Nov. 19, 1963 D. A. CAVANAGH 3,111,484

MAGNETIC CONCENTRATION APPARATUS

Original Filed Jan. 5, 1953 4 Sheets-Sheet 1

FIG. 1

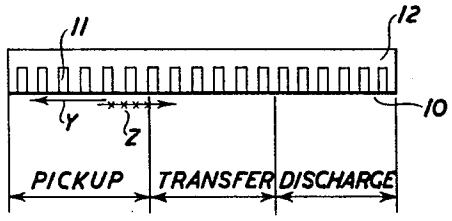
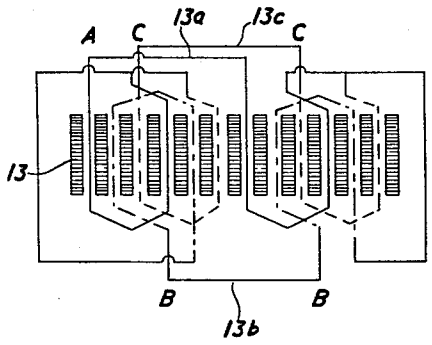


FIG. 2



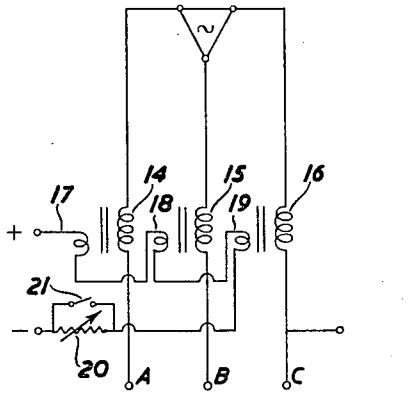


FIG. 3

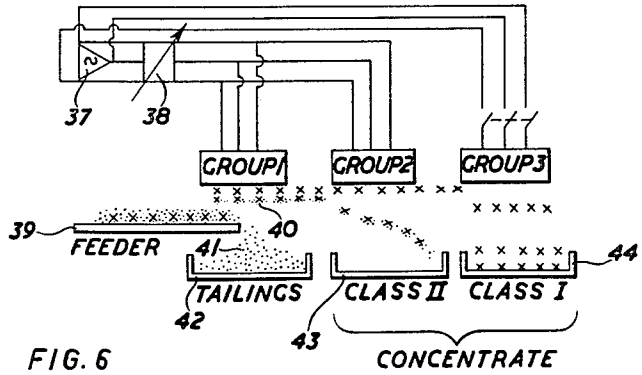


FIG. 6

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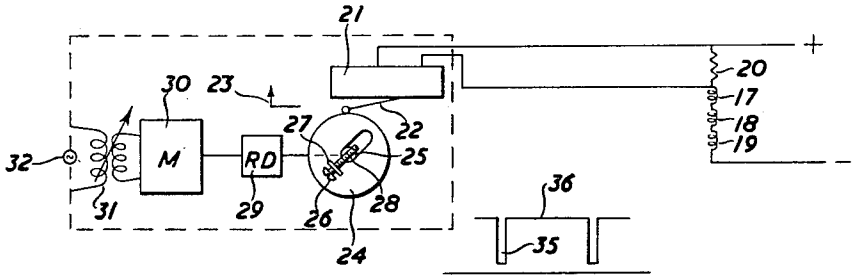
FIG. 4



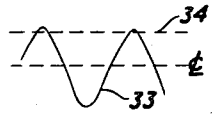


FIG. 5

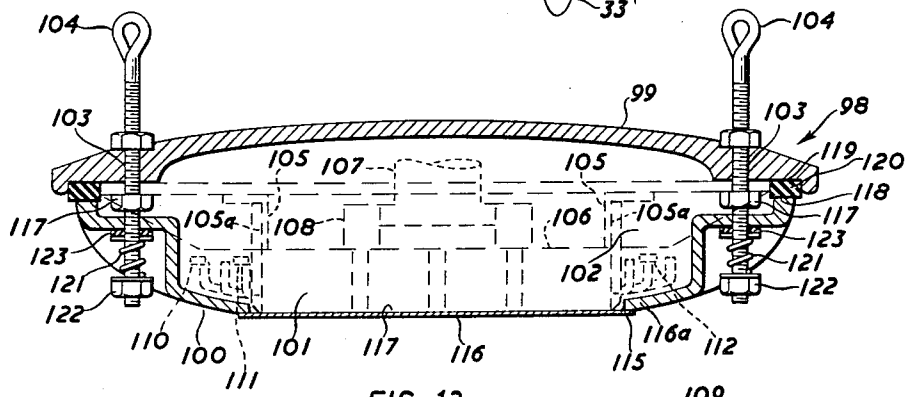


FIG. 12

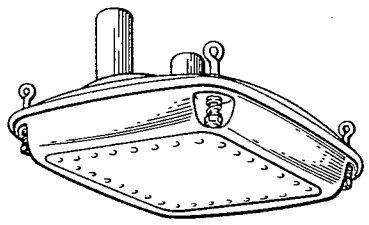


FIG. 13

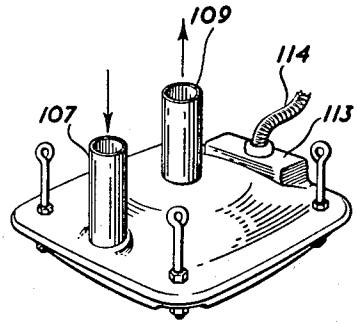


FIG. 14

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FIG. 7

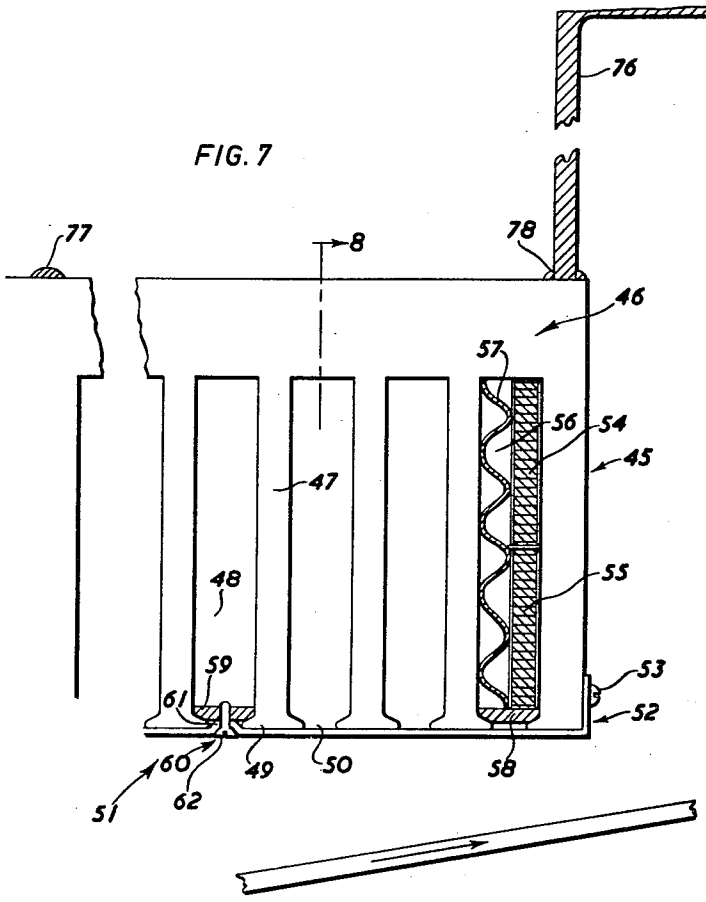
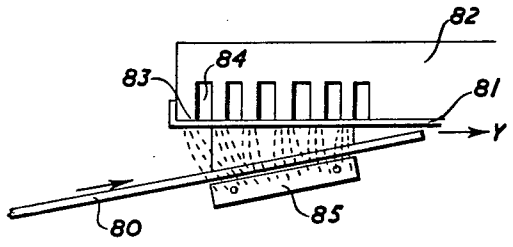


FIG. 10



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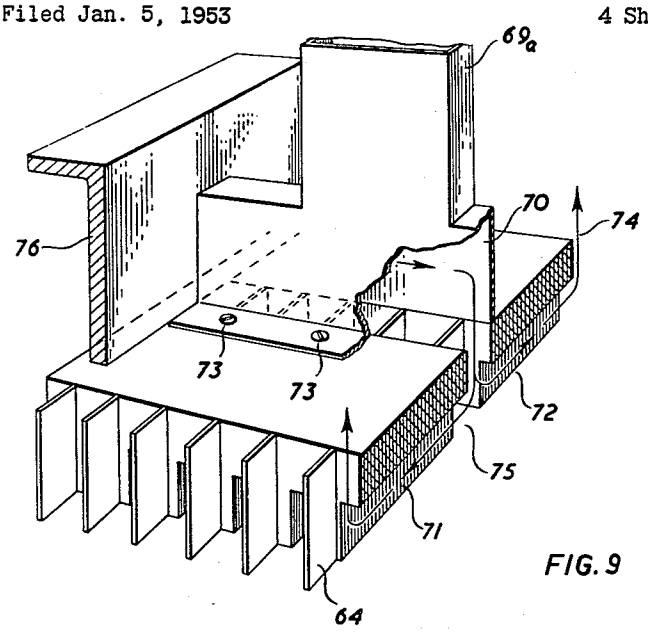
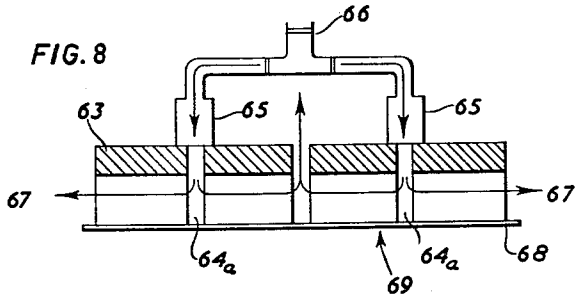


FIG. 9

FIG. 8



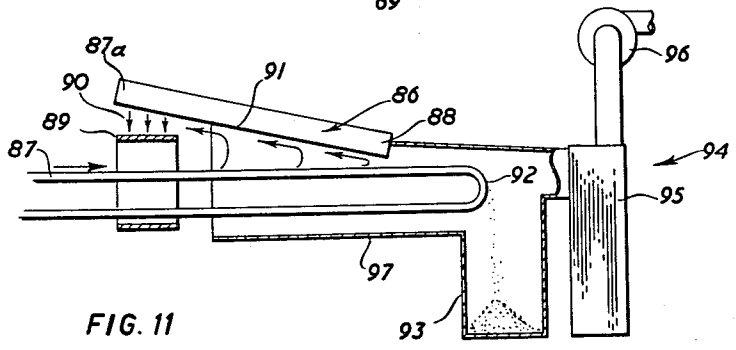


FIG. 11

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United States Patent Office 3,111,484 Patented Nov. 19, 1963

3,111,484

MAGNETIC CONCENTRATION APPARATUS

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Original application Jan. 5, 1953, Ser. No. 329,657, now Patent No. 3,045,821, dated July 24, 1962. Divided and this application Oct. 13, 1958, Ser. No. 767,030
18 Claims. (Cl. 209—227)

This invention relates to apparatus for separating magnetic particles from finely divided material and more particularly to improvements in concentration apparatus for the polyphase travelling field class of magnetic separation. This application is a division of application Serial No. 329,657, now Patent No. 3,045,821, granted July 24, 1962.

It is known that prior polyphase travelling field magnetic separators are seriously limited in capacity. The flux density which can be developed for the purpose of providing a travelling field in the magnetic core construction of prior apparatus is limited to an extent making such devices impractical for many applications. In such prior apparatus, a large number of poles have been provided in the core structure of the device in order to accomplish separation efficiency, by arranging a large plurality of such poles equidistant from and close to a conveying device for the materials being separated. The characteristics of such devices of the analogous prior art are outlined in a paper titled "Three-Phase A. C. Can Improve Fine-Size Magnetic Separation," published in Engineering and Mining Journal of October 1951 by McGraw-Hill Publishing Company of New York. According to the established art, the desired separation effect has been accomplished mainly by providing a large number of poles numbering seventy-two or more.

It is a main object of the present invention to provide a polyphase travelling field magnetic separator of a relatively small number of poles comprising pickup and discharge groups.

Another object of the invention is to provide a sloped mounting of a travelling field magnetic separator with respect to the finely divided material conveyor or feeder therefor whereby the major separation effect practised upon the material is accomplished in the step of lifting the material from the conveyor.

A further object of the invention is to provide an improved construction of travelling field magnetic separator embodying a winding assembly wherein the windings are directly cooled.

A still further object of the invention is to provide improvements in polyphase magnetic separators wherein the physical size of the poles and the spaces therebetween, are unlimited except by the largest size of magnetic material desired to be handled and the properties of the core material.

A still further object of the invention is to provide a cleaning of the concentrate obtained by a travelling field magnetic separator by the use of an air stream.

A still further object of the invention is to provide an automatic discharge device operative by the removal of a portion of the magnetic field from a portion of the core of the separator.

A still further object of the invention is to provide a cover sheet for the core, of a magnetic material specifically for the purpose of shaping the field generated from the poles in contrast to prior practice of employing non-magnetic materials for such a cover sheet.

A still further object of the invention is to provide a field shaping core associated with the core of the separator in such manner that the conveyor or feeder device passes therebetween.

It is a still further object of the invention to provide

a travelling field magnetic separator of high intensity operative upon weakly magnetic materials.

Other objects of the invention will be appreciated by a study of the following detailed specification taken in conjunction with the accompanying drawings.

In the drawings:

FIGURE 1 is a diagrammatic view of the core arrangement of a polyphase travelling field magnetic separator device illustrating pickup, transfer and discharge sections thereof;

FIGURE 2 is an electrical schematic laid over a plan view of a pole diagram of the core of FIGURE 1, illustrating the preferred type of winding for such core according to the invention for two active sections such as a pick-up section and a transfer section;

FIGURE 3 is an electrical schematic of a system according to the invention for providing discharge of material from the magnetic separator device;

FIGURE 4 is a diagrammatic view of actuating means for the discharge electrical apparatus of FIGURE 3;

FIGURE 5 illustrates a manner of modulating the current in the windings of the discharge section of the separator with the device of FIGURE 4 in conjunction with the electrical schematic of FIGURE 3;

FIGURE 6 is a diagrammatic view of the device of the invention, including an electrical schematic of the manner in which separation of materials may be controlled by controlling the voltage of the winding groups of the separator core;

FIGURE 7 is a partial sectional view of the core construction for a polyphase travelling field magnetic separator according to the invention, particularly illustrating a method of directly cooling the windings thereof and also illustrating a preferred manner of disposing the separator with respect to a conveyor for material being fed thereto, while revealing a modification in the design of the strip slot;

FIGURE 8 is a diagrammatic view of a method of, and apparatus for, cooling a polyphase travelling field magnetic separator core and windings therefor according to the invention, being illustrated as a sectional view;

FIGURE 9 is a perspective view of a modified polyphase travelling field magnetic separator core construction according to the cooling arrangement illustrated in FIGURE 8;

FIGURE 10 is an illustration of a field shaping device according to the invention associated with a magnetic separator core and a conveyor for the material;

FIGURE 11 illustrates a preferred method of feeding material to a polyphase travelling field magnetic separator in conjunction with means for air cleaning the concentrate as it is obtained wherein the tailings are disposed at a point considerably beyond the margins of the separator device;

FIGURE 12 is a sectional view of one preferred form of construction of magnetic separator according to the invention, illustrating the form of housing therefor whereby the device is sealed and may be partially immersed in liquids if desired;

FIGURE 13 is an underside perspective view of the device of FIGURE 12; and

FIGURE 14 is a topside perspective view of the device of FIGURE 12;

Referring to the drawings and particularly FIGURE 1, the polyphase travelling field magnetic separator core 10 having slots 11 carrying three phase windings provides a travelling field moving in the direction of arrow Y which is adapted to carry magnetic material along the under face 12 in the direction of the arrow Z.

I designate that portion of the under surface or working face 12 disposed over the feed conveyor, a "pickup" section or group of slots, which for a three phase winding,

may comprise at least six slots as indicated, or multiples of six. In many cases it is desirable to carry the material along the working face 12 from a position above the feed conveyor to a point remote therefrom at which the material may be discharged and accordingly I may designate a further group of slots as a transfer section or group. Finally, I may designate a final group of slots as a discharge section or group. While devices of the prior art of the present class of magnetic separator have laid stress upon the provision of a transfer section of a large number of poles to provide the separation efficiency desired, I have found that the efficiency of separation is not materially controlled by any such transfer section but is mainly controlled by the manner of picking up the magnetic materials from the feeding device. This is a critical concept in determining what may be the controlling factor in the capacity of apparatus of the present class.

In prior polyphase travelling field separators of the class considered herein, a half slot three phase winding has been used. I have found that this affects the capacity of pickup since the end slots of the core are only partially filled with windings resulting in a distorted flux at the pickup and discharge ends of the magnet. Thus, I may provide a full slot winding at the pickup end by employing a type of winding for the core as illustrated in FIGURE 2 for a three-phase power source and which may be recognized as a type of chain winding. A feature in applying this winding to a core construction according to the invention is illustrated in FIGURE 2 wherein it will be apparent that the windings A, B and C in star connection, are arranged between the pole legs 13 in accordance with a chain winding method but wherein the intermediate windings B are reversed for balance in a special manner according to the invention by merely taking the connections 13*b* for the windings on one side of the core construction carrying the poles 13, whereas the connections 13*a* and 13*c* for the other two phases are at the other side of the core construction as illustrated. This simple method of accomplishing reversing of the intermediate windings permits a facility of assembly and servicing of considerable advantage in the overall design of the apparatus.

Referring to FIGURE 3, the last three coils 14, 15 and 16 such as the last group of windings A, B and C of FIGURE 2, may be controlled by the control device of FIGURE 3 to effect a momentary limitation of the current in said coil whereby the flux therein will be insufficient to hold magnetic material against the working face of the core 10 of FIGURE 1 in the discharge section of the separator. By reason of the heavy currents involved in the development of high flux densities at line voltages, I have found it undesirable to merely switch or sever the current in this last winding section and according to the invention, provided the control device of FIGURE 3, supplied by a three phase source of power wherein saturable reactors 14, 15 and 16 having direct current windings 17, 18 and 19 respectively, control the amount of current in the last three coils or windings or in those coils or windings comprising the discharge section of the device. In place of saturable reactors, I may use any other current modulating device such as a saturable transformer, thyratron or ignition control device.

The direct current windings are preferably connected electrically in series with a control variable resistance device 20 to a source of direct current as illustrated and including a switching device 21 in parallel with the resistance 20 whereby the direct current windings noted may be placed directly across the direct current source or in series with the resistance 20. The resistance 20 should be of a value bringing the impedance of each saturable reactor to a value greater than about three times the impedance of the discharge winding which it serves. In this way, the magnetic field in the discharge section will be brought to a sufficiently low value that magnetic material will be released therefrom. On the other hand and

according to the invention, the maximum flux density in the core at the discharge section should be equal to or greater than the flux density in the transfer section of FIGURE 1 or if no transfer section is provided, then it should be greater than the flux density in the pickup section.

The switch 21 must be controlled in its time cycle and can only be open for a short period of time; otherwise the material ready for transfer to the discharge section will build up and cause a choking effect. Accordingly, the flux is reduced in the discharge section of the core for a period of time between one-tenth of a second and one-half of a second. Too short a period of time does not permit the magnetic particles to fall a sufficient distance to be free of the influence of the magnetic field of the discharge section. On the other hand, if the time period at very low or negligible flux density is unnecessarily long, the capacity of the device may be limited by a choking condition. The rate at which the discharge section is covered by the material from the pickup section is the controlling factor and this is determined by the size of the magnetic materials; a faster rate of covering being experienced with larger sized particles.

Therefore, with coarse magnetic materials, I may provide a discharge section having twice the number of slots than serve in the pickup section. Even when the discharge section has the same number of slots as the pickup section, it is possible by limiting the discharge time to about one-tenth of a second, to provide a capacity in the discharge section equal to about 95% of the capacity in the pickup section. This will involve a choking effect of about 5% of the magnetic materials. However, by increasing the field strength of the discharge section by a factor of about 5%, the capacity of the discharge section can be brought up to the capacity of the pickup section and this forms an important part of the present invention. It will be apparent that since the discharge section will operate at a lesser duty cycle than the pickup section, the winding may be the same design in both sections, within limits appreciated by persons skilled in the art.

I provide a time cycle control for the discharge section in the manner illustrated in FIGURES 4 and 5 wherein the pressure switch 21 which may be of any suitable known construction having a switch arm 22 and being of a normally closed class, is adapted to be opened by depressing the arm 22 above the line 23 as indicated. This may be accomplished by providing an adjustable circular cam wheel 24 on shaft 25 adjustable in eccentricity by means of the screw 26 passing through the brackets 27 on the cam and in threaded engagement in the threaded bore 28 of the shaft 25. The shaft 25 is driven by a gear reduction device 29 driven by a motor 30 controlled in speed by a variable transformer 31 connected to a suitable source of alternating current 32. The switch 21 is connected in parallel with the resistor 20, the latter being in series with the direct current windings of the saturable reactor coils 17, 18 and 19 as indicated.

In operation, the cam wheel 24 traces a motion indicated in curve 33 in accordance with the desired adjustment to actuate the switch 21 at a mechanical switching level corresponding to the line 34 at which the switch will be actuated to the open position for the period indicated by the width of the valleys of the square wave 35 in the upper portion of the diagram but wherein the current in the direct current winding decreases to the value as at 35. Observe that when switch 21 is closed, the current in direct current reactor windings is at the level 36 at which the flux density in the discharge section is a maximum. In this way, modulation of the current in the discharge windings is effected by controlling currents of small magnitude.

A general arrangement of overall control of the flux density of the various sections of the core of the separator is illustrated in FIGURE 6 wherein the windings for the pickup, transfer and discharge sections are designated as groups 1, 2 and 3, respectively. The coil groups 1 and 2

preferably are served by a three phase source of alternating current 37 through a variable transformer 38 leaving the third group for the discharge section to be served directly from the source of current 37, so that the flux density of groups 1 and 2 may be adjusted to a flux density lower than the flux density of the discharge group, to avoid choking. A feeding device 39 such as a magnetic vibrating feeder, is shown feeding magnetic material mixed with non-magnetic material to the first group at which the magnetic material 40 is picked up and the non-magnetic material 41 falls into a tailings bin 42. As indicated at group 2, part of the magnetic material may fall away into a bin 43 which material may be of a class II type of concentrate or a middling, wherein the magentic particles may have attached thereto, non-magnetic material. The purer concentrate proceeds to the discharge group 3 and is released therefrom in the manner previously explained to fall into the bin 44 to constitute a class I concentrate.

Where the group 2 section of the core serves as a part of group 1, that is, it is effective in pickup of material from the feeder and is disposed over the feeder, no middlings will be obtained and the resulting concentrating treatment will deliver a concentrate and a tailing only. On the other hand, where the second group forms part of the discharge group, no middlings will be obtained and this is the preferred manner of operating the device of the invention.

As is well known, the strength of the magnetic field need not be very great to pick up magnetic particles and with magnetic separators of the present class but of the prior art, a flux density in the core structure of about 2,500 gauss has been found satisfactory for picking up magnetic material providing the feeder is positioned close to the working face of the magnet. However, the capacity of such prior art core constructions for conveying the lifted material to the discharge end of the magnet, is seriously limited by the flux density in the magnet core.

It is undesirable with prior art methods to increase the flux density of the core above that sufficient to pick up the desired magnetic material from a feeder disposed closely to the surface of the pickup section of the core. However, according to the present invention, the pickup field strength is controlled relative to the particles being lifted, not by limiting the flux operated in the core construction, but by placing the material feeder a relatively large distance from the face of the pickup section while providing a large flux density in the core construction to deliver a large handling capacity for the separator. In this way, a deeper bed of feed can be fed to the pickup section of the working face of the separator core without the proximity of the working face of the core seriously limiting the depth of feed thereto in relation to the capacity of the device.

It will be apparent to skilled persons that the problem of providing a high flux density core construction of generally shallow rectangular form presents a problem of the worst sort in electrical design because the general core construction is of insufficient depth to develop practical convection cooling by air. The laymon may visualize that with an open-ended core construction of the present type, the problem corresponds substantially to the case of removing the rotor from an induction motor and applying current to the stator windings. Under such conditions, the stator would be limited to a flux density of probably less than 2,000 gauss, with permissible temperature rises under conditions of natural cooling. While very large core constructions may be visualized wherein the centre to centre distance between poles is of the order of four inches or greater where natural air cooling may be employed while developing flux densities in the core of a value near to or at the saturation point, it must be realized that such large structures are accompanied by problems associated with the character of a face-covering sheet and the structural support of the core against bending.

Thus, referring to FIGURE 7, the core construction 45 comprised of laminations 46 having poles 47 separated by winding openings 48 terminating in pole spaces 49 separated by slots 50 and the working face 51 thereof, is covered in its working face by a covering sheet of material 52 tensioned and fastened as by the screws 53.

The present invention therefore contemplates a sheet tensioning system as hereinafter disclosed in more detail in respect to FIGURES 12 to 14, particularly practical for those sizes of core construction which must necessarily be cooled by some means to develop a reasonably high flux density therein.

In the device of the present invention, a special cooling system is employed as indicated in FIGURES 7 to 9 wherein windings 54 and 55 are placed in the winding opening 48 in such manner as to leave an air passage 56 therethrough, such windings being preferably held in place by open structured retaining means 57 such as an undulated or corrugated sheet of fibrous material. The whole assembly is held in winding opening by means of a conventional form of fibre slot strip 58. If desired, a modified design of strip slot 59 may be employed, to which may be fastened the sheet 53 by means of screws 60 at various points on the underside of the core construction. I prefer, however, to leave the working surface 51 of the core construction completely free of obstruction and while the sheet 52 is shown as indented as at 61 to effectively countersink the head 62 of screw 60, I prefer to avoid such construction unless found to be essential over very large core surfaces where the sheet 52 may be discontinuous and may be comprised of a plurality of separate edge sealed sheets.

As will be evident from an examination of FIGURE 8, the core is built up from a plurality of laminated sections 63 which may be four in number, the sections being spaced by separators 64 in the form of rigid plates welded thereto as indicated in FIGURE 9 along the pole legs whereby air or other cooling medium may be forced from manifolds 65 connecting to a common source pipe 66 continuously into two of the longitudinal slots 64*a* to follow a flow path as indicated by the flow line arrows. The cooling medium passes directly over the surfaces of the windings to exit at the ends 67 of the overall construction and at the midslot exits thereof as indicated. The spaces or slots between the sections receiving inlet cooling medium are commonly connected by some manifold construction as indicated, the outlet slots and openings being free to permit the exhaust of the cooling medium to the inner confines of any suitable housing (not shown) extending thereabout.

Observe that a continuous sheet 68 on the working face 69 seals this working face against escape of the cooling medium.

In FIGURE 9, a modification of the cooling arrangement is illustrated in that the core construction is shown wherein the inlet cooling medium is brought in by way of a common duct 69*a* into a manifold 70 of sheet metal fastened to the core pieces or sections 71 and 72 by means of suitable screws 73 as shown. Arrow lines 74 indicate the manner of flow of the cooling medium from the centrally located ventilating slot 75 outwardly through the core construction.

As indicated in FIGURE 7, the ends of the core sections are all commonly welded or otherwise joined to a supporting angle 76 whereby the complete core may be mounted in a suitable housing if desired. The laminations of the core are held in assembly by transverse seam welds as indicated in FIGURE 7 at 77 and 78, 360 electrical degrees apart along the upper surface of the core above every seventh pole for the winding arrangement shown. The sides of the core are supported in the manner discussed in more detail hereinafter with reference to FIGURE 12.

Many experiments have shown that an undesirable effect arises in feeding material to the pickup section of a magnetic separator of the type depicted in the prior art,

as will be evident from an examination of FIGURE 10, illustrating an improvement according to the invention. A conveyor **80** such as a vibrating feeder, if directed in the direction of material conveyed by the working face **81** of core **82** as in the direction of the arrow Y must force the fed material against the end field pattern of the core **82**, the condition sometimes causing a choking of material at the point of pickup particularly if the feeder is arranged to feed the material closely to substantially the first pole only of the core. I avoid this condition by any one of three methods which limit choking effects, or all of these methods combined as indicated in FIGURE 10. Thus, I may provide a sheet **81** of a magnetic material such as a sheet material of core lamination sheet metal so that although the pole ends **83** may be substantially square as indicated, with substantially square slots **84**, the effective pole end shape will be of a rounded nature in respect to the field pattern therefrom. In this way, a more uniform field is generated from the pole. Secondly, more particularly to avoid a field interference effect with the feeding arrangement illustrated in FIGURE 10, the feeder **80** is positioned at an angle with respect to the core so that the magnetizing force is very small as the fed material enters the field near the first pole **83**. It will be apparent hereinafter that I prefer in any case to incline a conveyor or feeder with respect to the working face **81** for improving selectivity of pickup of material therefrom. Another method of controlling the effective field at the pickup end of the magnet when feeding in the direction of conveyance along the magnet, involves a field shaping device **85** built up of laminations of the same material from which the core **82** is made. The field shaping pole piece **85** may be of a length less than the pickup section of the core to shape the field mainly at the first pole of the pickup section.

I have discovered that I may provide an optimum feed capacity to a separator device of the class described herein while avoiding choking at all rates of feed and while feeding material to a substantial depth on the conveyor by feeding material to the separator in the opposite direction from that used heretofore.

As indicated in FIGURE 11, a magnetic separator of the travelling field class designated by numeral **86** may be positioned over a feeder conveyor belt **87** so that the belt moves in a direction under the separator from the discharge end **87a** thereof to pickup end **88** thereof. A concentrate belt **89** is disposed transversely of the separator **86** and the feeder belt **87** to carry away concentrate dropped in the direction of the arrows **90** from the discharge end of the separator. The material on the conveyor **87** is drawn toward the working face **91** at an increasing attractive force as the material is moved closer to the pickup end **88**. A bed of material may be fed on the belt **87** so that the bed is agitated by the increasing magnetic field as the material proceeds below the separator. Thus the whole undersurface of the separator is effective as a combined pickup and transferring section, with the exception of the discharge section *87a*.

Observe that the conveyor **87** projects beyond the marginal edges of the separator **86** to a tailings discharge point **92** positioned a substantial distance from the separator and adapted to discharge tailings into a suitable bin **93**.

An air cleaning system **94** may be employed in conjunction with the tailings discharge bin such as a bagging machine **95** or cyclone separator as may be preferred, operative by an air fan **96** and associated with an air enclosure or housing **97** extending over the feed belt **87** and the separator up to the discharge section *87a* thereof and the concentrate conveyor **89**. In this way, a feature of the invention is provided in a reverse draft or counter-current air system in the region of the pickup of magnetic material from the conveyor **87** whereby the concentrate is air scoured during pickup and the whole operation may be maintained effectively dustless.

In FIGURES 12 to 14 I show a preferred form of housing construction for a magnetic separator according to this invention embodying automatic tensioning means for the cover sheet of the working face thereof and adapted to entirely seal the separator from dust and permit the working face of the separator to be submerged in a liquid for wet separation practice, if desired.

In FIGURE 12, the housing **98** is shown comprised of two main parts: a top cover **99** or body part and an under cover or closure part **100**. While a cast metal construction is illustrated, a built-up form of construction may be employed, if desired. The separator core **101** is illustrated in chain lines, being supported by transversely extending angle members **102** extending outwardly to be fastened to the body **99** by means of eye bolts **103** passing therethrough and extending upwardly beyond the body to present loops **104** adapted to be connected to cables or to be rigidly fastened to suitable framing, as may be desired. As reviewed in respect to the construction of FIGURES 7 and 9, the transverse angle member **102** connects to the core **101** and transversely supports the latter against bending due to its weight. Lengthwise bending of the core may be provided against by the longitudinally extended angles **105** welded to the side edges of the core to the face **106** thereof. The angles **105** have welded thereto on the outer surfaces of the upright legs thereof, tooth supports **105***a* in the form of rigid plates similar to the core spacers **64** of FIGURE 9 but of greater height for securement to the angle **105** and acting to retain the leg or tooth portions of the core in compressive assembly.

As indicated in FIGURES 13 and 14, an air inlet pipe **107** commuicates with manifold **108** to the core **101**, the exhaust of air from the core flowing into the confines of the housing and escaping from the outlet **109**. In a three phase type of core, chain wound as set forth herein, connection for two phases may be made by cables **110** and **111** on one side of the core and the connection for the intermediate reverse windings such as by the cable **112** on the other side of the core. These cables, along with other cables for the discharge windings, are brought to a connection box **113** and through a main cable **114** to suitable controlling transformers and the three phase source of power.

A feature of the invention resides in the provision of an undercover **100** having an opening **115** extending freely about the marginal edges of the separator core and carrying a cover sheet **116** fastened thereto, preferably by machine screws **116***a*. The bolts **103**, as before mentioned, support the core by the angle **102** by means of the nuts **117** suspending the apparatus free for servicing. The cover **100** is placed over the exposed parts of the apparatus the edges **118** thereof co-operating with sealing edges **119** of the top cover to form a seal in conjunction with the resilient rubber gasket **120**. The undercover is held in place by means of strong springs **121**, compressed by means of the nuts **122** on the lower extending portions of the bolts **103**, a dust seal being effected by means of the compressible washer **123** of rubber or other suitable material.

Accordingly, as the pressure of springs **121** is increased by tightening the nuts **122**, the tension in the sheet **116** will increase. So long as the stresses in the sheet **116** are set to values less than the elastic limits of the material, tensioning of the sheet **116** over the under face **117** of the core by engagement therewith, will permit compensation for thermal expansion of the sheet **116** within a limited range of temperature.

Prior apparatus of the present class being capable of handling small particle sizes only, necessitated the overgrinding of many ores. I have found that the larger the interpole distances (centre to centre of adjacent poles), the larger the diameter of particle which may be handled, providing a sufficient flux density is available. Moreover, larger particle sizes move at greater speed along the working face of the separator core, thus permitting much greater capacities with core constructions of the invention

having much larger interpole spacing than heretofore contemplated, and having directly cooled windings enabling high flux density to be developed.

In accordance with this concept, the capacity of the present class of separator may be increased to as much as ten times the capacity available heretofore. The novel method of inclining the material feeder relative to the working face of the present class of separator frees the present method of separation from capacity limitations formerly imposed by other methods. The method of providing an increasing strength of field from the pickup section of the separator to the discharge section thereof by operating the latter at higher flux density avoids capacity limitations derived from choking effects.

Thus, one may prepare a material by grinding to optimum size, i.e., to a size only sufficiently small to liberate the desired purity of magnetic particle after which the prepared material is fed to the separator at an angle with respect to the working face thereof as set forth.

According to the invention, I provide apparatus for magnetically concentrating such material including the separator core structure and related devices. The invention also relates to the method of magnetically concentrating such material wherein the material is moved in the ways described toward a sheet along which a travelling magnetic field moves and through which such field extends toward said material.

I claim:

1. Magnetic material concentrating apparatus, comprising:

(*a*) a core structure having a working face,

(*b*) means connectable with a source of electrical power for generating a travelling magnetic field along said working face in a predetermined direction, and

(*c*) means for moving material at an angle toward said working face, in a direction the same as the direction of travel of said magnetic field therealong and along a path of substantially greater length than a dimension of said working face.

2. Magnetic material concentrating apparatus comprising:

(*a*) a core structure having a working face,

(*b*) means connectable with a source of electrical power for generating a travelling magnetic field along said working face in a predetermined direction,

(*c*) means for feeding material to said working face in a direction the same as the direction of travel of said magnetic field therealong, and

(*d*) means for moving a current of air adjacent said working face in a direction substantially opposed to the direction of motion of magnetic particles along said working face, thereby effectively removing non-magnetic particles entrapped within said magnetic particles.

3. Magnetic material concentrating apparatus, comprising:

(*a*) a core structure having a working face,

(*b*) means connectable with a source of electrical power for generating a travelling magnetic field along said working face in a predetermined direction,

(*c*) means for moving material at an angle toward said working face, in a direction the same as the direction of travel of said magnetic field therealong and along a path of substantially greater length than a dimension of said working face, and

(*d*) means for moving air adjacent said working face in a direction substantially opposed to the direction of motion of magnetic particles therealong, thereby removing non-magnetic particles entrapped within said magnetic particles.

4. Magnetic material concentrating apparatus, comprising:

(*a*) a core structure having a working face,

(*b*) means connectable with a source of electrical power for generating a travelling magnetic field along said working face in a predetermined direction,

(*c*) means for conveying material at an angle toward said working face, in a direction the same as the direction of travel of said magnetic field therealong and along a path of substantially greater length than a dimension of said working face,

(*d*) means for moving air adjacent said working face in a direction substantially opposed to the direction of motion of magnetic particles therealong, thereby to remove non-magnetic particles entrapped within said magnetic particles, and

(*e*) means supporting said core structure to dispose the working face thereof over said conveying means between the ends of said path and at an angle with respect thereto so that the material thereon moves closer to said face as it is conveyed along said path, said path projecting beyond said working face a distance sufficient to remove said material to a position outside the influence of said magnetic field.

5. Magnetic material concentrating apparatus, comprising:

(*a*) a core structure having a working face,

(*b*) means connectable with a source of electrical power for generating a travelling magnetic field along said working face in a predetermined direction,

(*c*) means for conveying material at an angle toward said working face, in a direction the same as the direction of travel of said magnetic field therealong and along a path of substantially greater length than a dimension of said working face, and

(*d*) means supporting said core structure to dispose the working face thereof over said conveying means between the ends of said path and at an angle with respect thereto so that the material thereon moves closer to said face as it is conveyed along said path, said path projecting beyond said working face a distance sufficient to remove said material to a position outside the influence of said magnetic field.

6. Magnetic material concentrating apparatus comprising:

(*a*) a core structure having a working face,

(*b*) means connectable with a source of electrical power for generating a travelling magnetic field along said working face in a predetermined direction,

(*c*) means for conveying material to said working face in a direction the same as the direction of travel of said magnetic field therealong,

(*d*) means for moving a current of air adjacent said working face in a direction substantially opposed to the direction of motion of magnetic particles along said working face, thereby effectively removing non-magnetic particles entrapped within said magnetic particles, and

(*e*) means supporting said core structure to dispose the working face thereof over said conveying means between the ends of said path and at an angle with respect thereto so that the material thereon moves closer to said face as it is conveyed along said path, said path projecting beyond said working face a distance sufficient to remove said material to a position outside the influence of said magnetic field.

7. The magnetic material concentrating apparatus as claimed in claim 1 including:

(*d*) control means for effecting a momentary limitation of the current in the discharge section of said working face whereby the flux will be insufficient to hold magnetic material against said working face in said section.

8. The magnetic material concentrating apparatus as claimed in claim 2 including:

(*e*) control means for effecting a momentary limitation of the current in the discharge section of said working face whereby the flux will be insufficient to hold magnetic material against said working face in said section.

9. The magnetic material concentrating apparatus as claimed in claim 3 including:

(*e*) control means for effecting a momentary limitation of the current in the discharge section of said working face whereby the flux will be insufficient to hold magnetic material against said working face in said section.

10. The magnetic material concentrating apparatus as claimed in claim 4 including:

(*f*) control means for effecting a momentary limitation of the current in the discharge section of said working face whereby the flux will be insufficient to hold magnetic material against said working face in said section.

11. The magnetic material concentrating apparatus as claimed in claim 5 including:

(*e*) control means for effecting a momentary limitation of the current in the discharge section of said working face whereby the flux will be insufficient to hold magnetic material against said working face in said section.

12. The magnetic material concentrating apparatus as claimed in claim 6 including:

(*f*) control means for effecting a momentary limitation of the current in the discharge section of said working face whereby the flux will be insufficient to hold magnetic material against said working face in said section.

13. The magnetic material concentrating apparatus as claimed in claim 7 including:

(*e*) time cycle control means in association with said control means and adapted, in conjunction with said control means, to effect said momentary limitation of current at a predetermined interval and for a length of time dependent upon the size of material being processed.

14. The magnetic material concentrating apparatus as claimed in claim 8 including:

(*f*) time cycle control means in association with said control means and adapted, in conjunction with said control means, to effect said momentary limitation of current at a predetermined interval and for a length of time dependent upon the size of material being processed.

15. The magnetic material concentrating apparatus as claimed in claim 9 including:

(*f*) time cycle control means in association with said control means and adapted, in conjunction with said control means, to effect said momentary limitation of current at a predetermined interval and for a length of time dependent upon the size of material being processed.

16. The magnetic material concentrating apparatus as claimed in claim 10 including:

(*g*) time cycle control means in association with said control means and adapted, in conjunction with said control means, to effect said momentary limitation of current at a predetermined interval and for a length of time dependent upon the size of material being processed.

17. The magnetic material concentrating apparatus as claimed in claim 11 including:

(*f*) time cycle control means in association with said control means and adapted, in conjunction with said control means, to effect said momentary limitation of current at a predetermined interval and for a length of time dependent upon the size of material being processed.

18. The magnetic material concentrating apparatus as claimed in claim 12 including:

(*g*) time cycle control means in association with said control means and adapted, in conjunction with said control means, to effect said momentary limitation of current at a predetermined interval and for a length of time dependent upon the size of material being processed.

References Cited in the file of this patent

UNITED STATES PATENTS

1,074,999	Zander	Oct. 7, 1913
1,463,713	Mordey	July 31, 1923
1,564,732	Weatherby	Dec. 8, 1925
1,692,590	Stearns	Nov. 20, 1928
1,897,763	Nicolet	Feb. 14, 1933
2,298,243	Widdows	Oct. 6, 1942
2,664,527	Reed	Dec. 29, 1953
2,853,657	Hofacker	Sept. 23, 1958

FOREIGN PATENTS

120,710	Sweden	Jan. 27, 1948
450,773	Italy	Aug. 9, 1949

OTHER REFERENCES

"Three Phase A.C. Can Improve Fine Size Magnetic Separation," by Suen Eketorp, Engineering and Mining Journal, vol 152, Issue 10, October 1951, pages 82, 83, 118.