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[54] **MAGNETIC DEVICE**
4 Claims, 7 Drawing Figs.

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 [51] Int. Cl. **B01d 35/06**
 [50] Field of Search **210/222,**
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209/38, 39, 40, 212, 213, 478, 223, 222, 227

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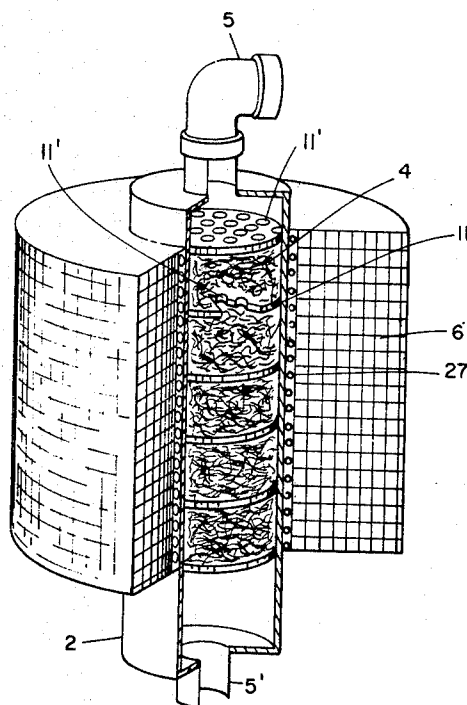
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ABSTRACT: Apparatus for separating colloidal and subcolloidal ceramic magnetic components from a slurry by passing the slurry through a column containing a magnetic material, as a magnetic grade stainless steel wool. The steel wool is subjected to a DC magnetic field to effect magnetization thereof and provides a large number of regions of very high magnetic field gradient along the paths of travel of the slurry to attract and retain the magnetic components. At intervals, the DC magnetic field is removed, and the steel wool is demagnetized. A preferred method of demagnetization is the application of an AC magnetic field, upon removal of the DC field, the AC field being gradually reduced to zero. Eddy current means is provided to apply an eddy current field to the steel wool to shake the components from said regions of the steel wool during the intervals.



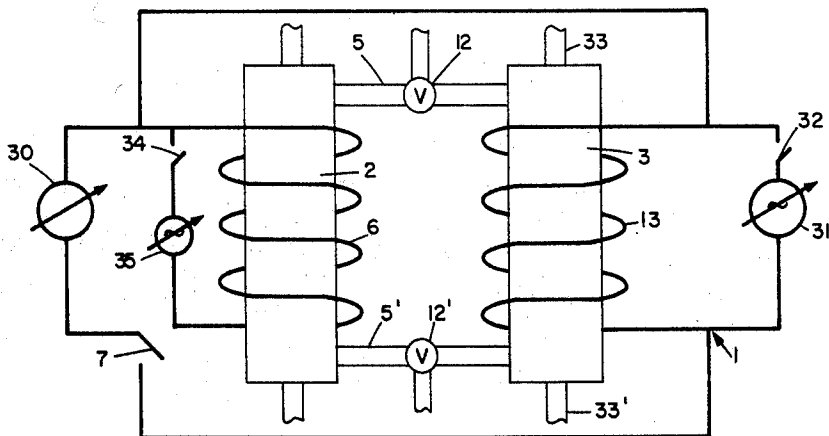


FIG. 1

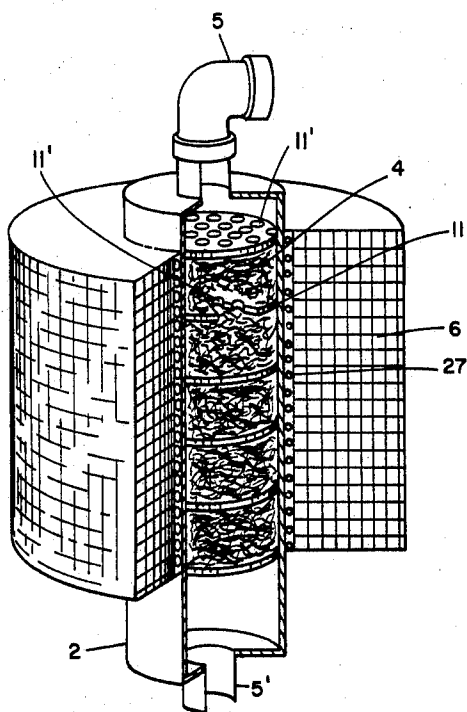


FIG. 2

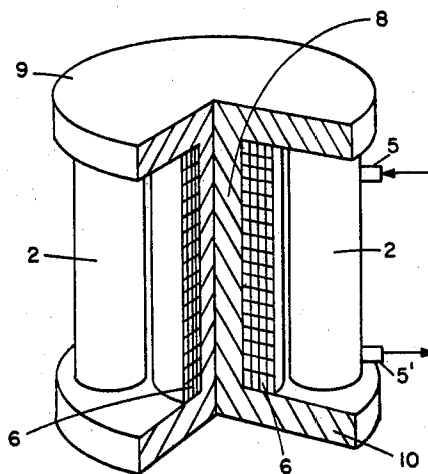
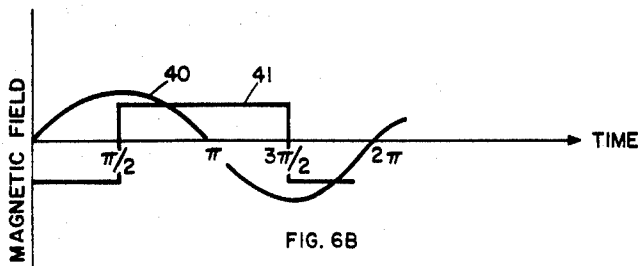
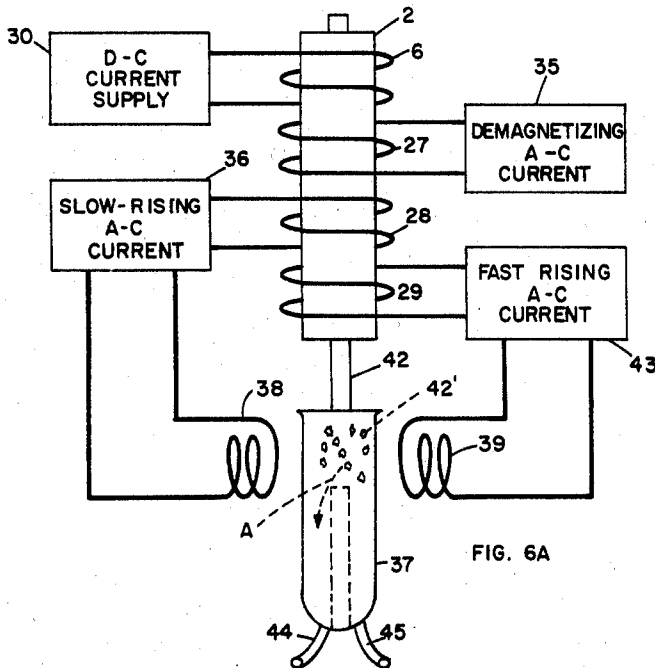
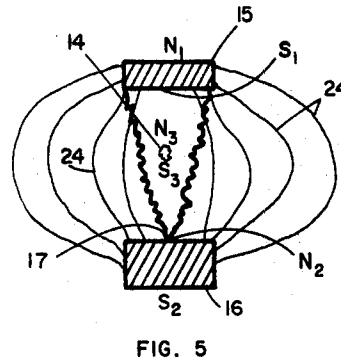
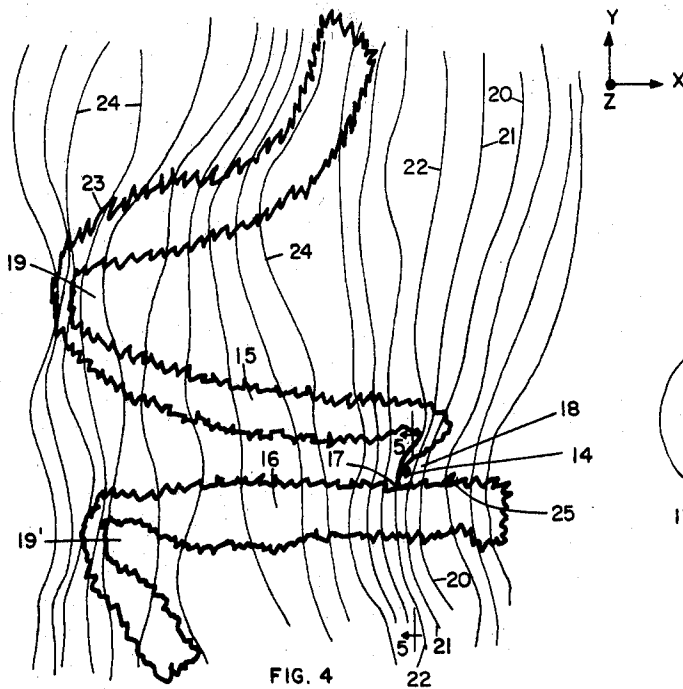


FIG. 3

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MAGNETIC DEVICE

This invention was made in the course of work performed under a contract with the Air Force Office of Scientific Research.

The present invention relates to separators adapted to remove magnetic and conductive nonmagnetic components from a slurry, the nonmagnetic components being removed by novel eddy current means other than separator apparatus.

It is frequently desirable to separate magnetic components from a slurry of predominantly nonmagnetic particles suspended in water or some other vehicle. The problem arises, for example, in ore dressing where the magnetic component may be an impurity or a usable mineral, and in the food industry where the magnetic component may be harmful steel chips introduced during a processing operation. To perform this separating function a number of "wet separators" are in common use. All of these rely on the technique of magnetizing the magnetic component by means of an applied magnetic field and simultaneously subjecting the magnetized particles to a divergent (fringing) magnetic field, that is, a magnetic gradient. The magnetic force experienced by each particle is directly proportional to three quantities: the induced magnetization of the particle, the size of the particle and the magnetic gradient. The effectiveness of a magnetic separator is directly dependent upon this magnetic force since this is the force which holds the magnetic particles against the competing forces of viscosity, turbulence and gravitation. Very little can be done to enhance the first of these quantities, the induced magnetization. If the substance being separated is ferromagnetic, its magnetization saturates in a moderate magnetic field and does not increase at higher field intensities. If the substance is paramagnetic, its magnetization increases linearly with the applied field intensity but is usually too weak in fields which can be applied in practice to be useful for separation although, as later discussed herein, the advent of practical superconducting magnets makes paramagnetic substances susceptible to magnetic separation on an industrial scale. The second quantity, particle size, is dictated by the intimacy of admixture of the magnetic component; and this usually (at least on the applications of most interest) requires that the parent substance be ground to colloidal size before magnetic separation can be effected. The third quantity, magnetic field gradient, therefore, is the crucial variable in the process; and its enhancement is of primary concern to designers. It is necessary not only to achieve the strongest possible field gradient, but also to produce it over a surface area large enough to collect a reasonable quantity of magnetic material before the capacity of the separator is exhausted. To achieve this aim, designers of the prior art use serrated steel plates, steel balls, wire mesh screens and ribbon mesh screens, usually arranged in multiple layers bridging the gap of an electromagnet. The types of separators just described are adequate only for separating magnetic particles of coarse size present in small quantities, and even under such favorable conditions their collecting area is so small that they require elaborate mechanical devices to move new collecting areas into the magnet continuously while the saturated area is being washed. The gradients produced in these known fabricated structures are so weak that effective separation requires flow rates so slow and retention times so long as to be unrealistic for industrial application in the majority of cases. It has been proposed, also, to provide loosely packed steel wool and iron filings as the magnetic filtration material, the material being placed between poles of permanent magnets, which rarely provide fields above 500 gauss, and electromagnets designed to achieve magnetic fields below 5,000 gauss. These latter separators fail to provide the high field gradients hereinafter discussed, and, furthermore, are not useful in connection with corrosive materials of great commercial interest as, for example, kaolin slurries, but appear to be useful for removing highly magnetizable particles from noncorrosive petroleum slurries.

Accordingly, an object of the present invention is to provide a separator employing a corrosion resistant ferromagnetic wool or the like adapted to remove magnetic components from a slurry or the like more completely and efficiently than is possible with the before-mentioned separators.

A further object is to provide separator apparatus which is adapted to remove colloidal and subcolloidal ferromagnetic components from a slurry or the like but which can be used to remove colloidal and subcolloidal ceramic magnetic components and paramagnetic components as well, and on an industrial scale.

In separators of the present invention, the ferromagnetic wool is placed in a high DC magnetic field which is reduced to zero at regular intervals to permit removal of trapped components from the wool by flushing. It has been found, however, that the wool retains some residual magnetization, and for this and other reasons a sizable amount of the components are not flushed from the separator. A further object of the invention is to provide means, and particularly eddy current means, adapted to vibrate the wool to shake loose retained components during the intervals of flushing.

Although the eddy current concept is particularly useful for the purposes discussed in the previous paragraph, it will be apparent in the discussion to follow that it has other novel utility as well. A still further object is, therefore, to provide eddy current apparatus of more general utility, including apparatus adapted to remove conductive particles, magnetic or nonmagnetic, from a slurry.

Other and still further objects will be evident in the specification to follow and will be particularly delineated in the appended claims.

By way of summary, the objects of the invention are attained, generally, in a magnetic separator adapted to remove magnetic components from a slurry or the like, that comprises, a magnetic material comprising randomly oriented corrosion resistant fibers adapted to provide a plurality of paths therethrough to effect intimate contact between the slurry and the fibers. Inlet means is provided to introduce the slurry to the column and outlet means to remove the slurry therefrom. Magnetizing means is provided to effect magnetization of the magnetic material. The fibers are compressed to a density sufficiently high to provide a multiplicity of regions of very high magnetic field gradient within the space occupied by the material to attract and retain the magnetic components at said regions.

The invention will now be described with reference to the accompany drawings in which:

FIG. 1 is a schematic representation of an embodiment of the present invention showing two columns for receiving a slurry containing magnetic components which are removed from the slurry and retained within the columns;

FIG. 2 is an isometric view, partially cutaway, of one column, and shows a magnetic material comprising randomly oriented corrosion resistant fibers adapted to separate the magnetic components from the slurry;

FIG. 3 is an isometric view showing a plurality of such columns disposed between magnetic pole pieces with a central magnetic core and coil adapted to magnetize the pole pieces;

FIG. 4 is a three dimensional view, on an enlarged scale, of two of the fibers shown in FIG. 2;

FIG. 5 is a view taken upon the line 5-5 in FIG. 4 looking in the direction of the arrows;

FIG. 6A is a schematic representation showing a column similar to the columns of FIG. 1 with means for magnetizing and demagnetizing the magnetic material within the columns and having, also, means for applying magnetic pulses to the material to effect vibration thereof, there being shown, as well, also schematically, an eddy current means for removing conductive materials, magnetic or nonmagnetic, from a slurry; and

FIG. 6B is a graph showing a sinusoidal wave to provide a slow-rising field for the eddy current means and a square wave to provide a fast-rising field therefore.

Referring now to FIG. 1 a magnetic separator 1 is shown for removing magnetic components, as steel particles or the like, from a slurry containing water or some other vehicle as the fluid carrier. The separator is useful to remove such magnetic components which may appear in the slurry as a foreign matter, or, in some instances, the magnetic components may be separated out for their own use. The separator 1 illustrated consists of two nonmagnetic casing tubes or columns designated 2 and 3, each of which contains a corrosion resistant magnetic material 4, as shown in FIG. 2. As explained hereinafter, there are times when two or more such columns may be used; but, for purposes of explanation at this point, it is necessary to refer to only one; and for that purpose the explanation now to be made will be made with reference to the column designated 2. The column 2 may be a single column, as that shown in FIG. 2, or it may consist of the plurality of the individual columns in FIG. 3 which may be connected in series or parallel to provide a composite column 2.

A preferred magnetic material 4 is a fine steel wool of magnetic grade stainless steel (other corrosion resistant ferromagnetic wools as nickel or others may be used) adapted to provide a plurality of paths therethrough to effect intimate contact between the slurry and the magnetic material, the slurry being introduced to the column through an inlet 5 and being removed therefrom through an outlet 5'. The steel wool is compressed to a density which gives it the desired specific magnetic reluctance, and, as later discussed herein, enough magnetic flux leaks through the voids between individual randomly oriented steel wool strands to create a column having a large number of regions of high magnetic gradient. The column 2 is subjected to a magnetic field by placing it with a coil 6, or the magnetizing means may be a yoke comprising a core 8 coupled at the ends thereof to a pair of pole plates 9 and 10. The fibrous material 4 is compressed to a density sufficiently high to provide a multiplicity of regions of very high magnetic field gradient within the column to attract and retain the magnetic components; it has been found, for present purposes, that the material should be compressed to achieve a specific permeability of the order of one-fourth to three-fourths the bulk reluctance of the steel wool or other ferromagnetic material of which the material 4 is made.

The present invention is, thus, adapted to provide a large number of regions of high magnetic field gradient, as more particularly explained hereinafter, along the paths of travel of the slurry to attract and retain the magnetic components. To affect the slurry, the regions mentioned must exist in the space through which the slurry passes in its movement through the column 2. If, for example, the reluctance of the magnetic material 4 in the column is nearly equal to the bulk reluctance thereof, the magnetic flux will be confined to the interior of the material 4; and little or no flux (i.e. environmental or background field) will be found in the path of travel of the slurry. On the other hand, as the amount of magnetic material approaches zero, the reluctance of the column will approach the reluctance of air, resulting in low flux density in the column 2 and effectively no regions of high magnetic field gradient. Thus, if the reluctance is too low, there is, in effect, a magnetic short circuit; and if it is too high, there is an open circuit. Magnetic steel wool is particularly suited for present purposes because the individual strands of the wool have directional and other discontinuities that cause magnetic flux to leave a strand and pass through the adjacent space. Thus, as the slurry passes axially through the column 2, the paths of travel provide intimate contact between the slurry and the magnetic material 4 at a multiplicity of regions of very high magnetic field gradient.

As previously mentioned, the vehicle or carrier fluid of the slurry can be water. Although other carrier fluids are of interest, water slurries are commercially of great importance; and it is necessary, when removing magnetic components, as here, from water or other corrosive slurries, that the material 4 used be corrosion resistant. Corrosion is particularly harmful in separators of the present type because, in addition to

destroying the complete fibers of the wool, it has the immediate effect of removing the serrated edges of the wool upon which the effectiveness of the present devices to a considerable extent depends, as later discussed in greater detail with particular reference to FIGS. 4 and 5. To prevent the harmful effects of corrosion in the present device, a magnetic grade stainless steel wool is used as the material 4.

The magnetics of the present invention will now be explained with particular reference to FIGS. 4 and 5, where two filaments or fibers of the material 4 are shown at 15 and 16. Assuming a DC magnetic field in the vertical or Y direction shown, a magnetic flux will exist, as represented, for example, by the lines designated 24. The flux lines will enter the fiber 15 to remain there for various distances depending, in part, upon the contour of the fiber in an X-Y or Y-Z plane. Thus, the flux 24 will leave the fiber 15 (and also the fiber 16) to create regions 18, 19 and 19', of very high magnetic field gradient within the volume of the material 4. The flux lines in the vicinity of the region 18 are numbered 20, 21 and 22. The lines 20 and 21 pass into the fiber 15, out into the region 18 and thence into the fiber 16 whereas the flux line 22 passes directly from the fiber 15 to the fiber 16 at the point of contact therebetween, designated 17. When fibers are used for the material 4, most of the flux passes through the region 18 as the point contact at 17 is a low reluctance path, and the fiber becomes saturated in the vicinity of the point as the cross dimensions thereof decrease. Furthermore, a large percentage of the contacts between fibers are of the point type shown in FIG. 4 so there is little tendency for a magnetic short circuit to exist. Also a large percentage of the volume occupied by the fibers consists of the regions such as 18, so there is, in a given volume, a considerable collecting area per unit volume available for retention of the magnetic components. Furthermore, the serrated profile of the fibers offers a large number of valleys, as 25, which also provide collection regions of high field gradient for the components. It should be noted, in this connection, that the magnetic components as they accumulate tend to short circuit the gaps, such as 18, thereby to reduce its effectiveness; thus, the increase in the percentage of the volume occupied by such regions is of more than negligible importance, and the detrimental effect of corrosion is evident.

The importance of a high field gradient can best be explained with reference to FIG. 5, where induced north and south poles within the fibers 15 and 16 are designated N_1 , S_1 and N_2 , S_2 , respectively, and the induced poles in a magnetic component 14 therebetween are designated N_3 , S_3 . The poles N_3 , S_3 have equal magnitude; so if the values of S_1 and N_2 are also equal and if the particle 14 is located half way between S_1 and N_2 , no movement will occur. Any change in the position toward either S_1 or N_2 will result in an unbalanced force upon the particle and movement toward the closest pole, assuming no other forces. But other forces as that due to slurry movement through the column 2, turbulence of the like tend to sweep the particle 14 away from either S_1 or N_2 . Only if the gradient is high and the forces due to S_1 and N_2 change very rapidly with changes in spatial position toward or away from either, will attraction be effective to remove and retain the components. In the present device, as mentioned, very high magnetic gradients are present.

The importance of the reluctance of the steel wool in the column 2 also becomes clearer after the explanation in the previous two paragraphs. As mentioned, when the fibers are saturated, the flux leaves the fibers at places of reduced cross dimensions; that is, at places where the reluctance in the fibers becomes greater than the reluctance of the adjacent air space, and the flux leaves also at places where the fibers are oriented to cross the field. And it is the flux lines (i.e. environmental or background field) in the adjacent air space which affect the magnetic components. But when the field strength within the volume occupied by the material 4 is low due, for example, to the high reluctance path in prior art devices resulting from the loosely packed wool, there is a tendency for the flux lines to pass through the fibers rather than into the space adjacent.

Therefore, three unfavorable conditions exist in separators with loosely packed steel wool: first, the field in the column is less for a given exciting field as might be effected between the pole plates 9 and 10; second, an inordinate amount of the magnetic flux in the column passes along through the fibers; and third, the distance between fibers will, on the average, be greater. The level of magnetic field gradient that exists in an operating separator is lessened due to the third condition discussed, and the number of regions where a field gradient exists is lessened due to the first and second conditions.

For the foregoing reasons the present device has many more collection points or stations for the magnetic components in a given volume than are present in prior devices, the regions of such points have a greater magnetic gradient than prior devices, and magnetic short circuits which become more pronounced as magnetic components are collected do not build as rapidly as they do in prior devices. Since the capacity of the present apparatus to retain the magnetic components far exceeds the capacity of prior devices, it can be used to filter magnetic components from a far greater quantity of slurry without flushing than previously known apparatus and do so in a far more efficient manner. Furthermore, colloidal and subcolloidal particles are removed with facility by apparatus embodying the present inventive concept.

As magnetic components are collected by the wool in increasing quantity, they gradually short circuit the collection regions forming paths for magnetic flux which bridge the magnetic gap. The paths are periodically broken during demagnetization, flushing and the vibration induced in the manner later discussed. However, to reduce the effect of such paths and other short circuits that occur, perforated equipotential plates 11 (made of magnetic-type stainless steel, for example) in FIG. 2, having perforation 11', are provided at intervals substantially at right angles to the direction of magnetic flux flow. The plates 11 are sufficiently massive to ensure uniform distribution of magnetic flux over the entire cross section of the separator to mitigate the bridging effect.

Turning again to FIG. 1, the apparatus illustrated, as mentioned, has two columns, the coil 6 being adapted to create an axial magnetic field in the column 2 and a further coil 13 being adapted to create an axial magnetic field in the column 3. The two columns shown allow cycling of the separator. Thus, a switch 7 may be closed to energize the coil 6 from a variable voltage DC source 30 while simultaneously removing a voltage from the coil 13, and electrically energizable valves 12 and 12' can be appropriately electrically interconnected to introduce slurry at the input 5 and remove it at 5'. At the same time a switch 32 is closed to introduce a voltage from a variable voltage AC source 31 to the coil 13 to remove any residual magnetism from the circuit. Clear water introduced at 33 and removed at 33' flushes magnetic components from the column 3. The switch 7 connected to the coil 6 can then be opened and the DC source 30 connected to the coil 13, and the column 2 can be flushed; a switch 34 and variable voltage AC source 35 serve the same purposes as the elements 32 and 31 before mentioned. Appropriate electrical interconnection to execute the foregoing operations is, of course, provided, and the AC sources 31 and 35 are controllable so that the current output of each can be made to decrease gradually to effect more complete demagnetization.

The described apparatus can be used with magnetic fields within the column of say 12,000 gauss, but fields of 20,000 gauss can also be used; and the coils 6 and 13 can be superconductive to provide fields of 40,000 to 100,000 gauss and above for removing paramagnetic impurities, for example. Ferromagnetic impurities are removed or separated at the lower fields, but even ferromagnetics are removed more effectively at the higher fields.

The strands of the steel wool have been called fibers and filaments. In fact, commercial stainless steel wool fibers, as shown in FIGS. 4 and 5, are flat ribbons with sharp, serrated edges having a thickness in the various grades about one-tenth the value of the typical predominant width dimensions given below:

Grade	Width
Very fine	0.002 inches
Fine	0.004 inches
Medium	0.006 inches
Coarse	0.010 inches

10 It should be noted, however, that the cross dimensions of the fibers in general are nonuniform and that the dimensions given are merely typical of the predominant fiber sizes. The grade used will depend upon the size of the impurities to be extracted, but the fine grade has been found to be best for colloidal and subcolloidal magnetic components although clogging of the filtration material must be considered.

As mentioned, the steel wool 4 is demagnetized during the flushing cycle; and this demagnetization may be accomplished by a relatively low intensity alternating magnetic field, the field being gradually reduced from some predetermined value to zero. The demagnetizing field can be applied using the same coil as applies the magnetizing field, as is shown schematically in FIG. 1. In FIG. 6A the demagnetizing field is provided by a separate coil 27 energized by the AC source 35, the coil 27 being shown in FIG. 2 would inside the coil 6. It is pointed out at this juncture that the coils 6 and 27 and later discussed coils 28 and 29 can be interleaved and arranged in various configurations to provide the desired field values. Thus, in FIG. 2, the coils designated 6 and 27 can include, also, coils to perform functions of the coils 28 and 29 discussed in the following paragraph. On the other hand, a single coil, as 6, in appropriate circumstances and proper switching, can be connected to perform the functions of the coils 6, 27, 28 and 29.

35 Work done in connection with separators employing the present invention has shown that complete demagnetization of the material 4 and collected components to allow flushing is not practically possible. Also, the magnetic components become secured at various regions in the material 4 in a manner that renders them difficult to dislodge. It is necessary, then, to furnish some means for vibrating the steel wool during the flushing cycle. A most effective vibration action can be supplied by the eddy current device now to be discussed. A sinusoidally alternating magnetic field 40 is FIG. 6B having a skin depth that is greater than the cross dimensions of the stainless steel fibers is supplied by the coil 28 which is energized by an AC current supply 36. The frequency of the current supply 36 is typically in the lower sonic range. A square wave alternating magnetic field 41 having an amplitude that is, preferably, lower than the sinusoidal wave 40 but which is $\pi/2$ radians out of time phase therewith provides, in combination with the field represented by the sinusoid 40, a vibratory action far greater than might be furnished, for example, by a single eddy current field as might be provided by a current having a frequency in the upper sonic range (i.e. 18,000—20,000 cycles) and connected to either of the coils 28 and 29 during the flushing cycle, although a single eddy current field may be used in particular apparatus. The square wave is supplied by the coil 29 which is energized by an AC current source 43 to furnish a square wave 41 at the same frequency as the frequency of the sinusoidal wave 40; but, whereas the sinusoid is slow rising and in the low frequency used (i.e. in the lower sonic range) has a skin depth that is large compared to the characteristic dimensions of the fibers, the square wave is abruptly alternating or faster rising and has a skin depth that is less than the characteristic dimensions of the fibers. The slow rising field 40 acts as a pulsed background field, the fast rising field 41 being applied to furnish a rate of change that is maximal when the background field 40 is also maximal thereby effecting a maximum vibratory force upon the steel wool. In some instances, it may be expedient to mix a small amount of copper wool in with the steel wool, the higher conductivity of the copper wool acting to increase the intensity of vibration within the column 2.

The previously discussed apparatus is adapted to remove magnetizable components from a slurry, but is not adapted to remove nonmagnetic components. The lower schematic representation in FIG. 6A comprising a nonconductive tank 37 connected in series with the column 2 by a pipe 42 is adapted to remove conductive components whether magnetic or nonmagnetic. The slow rising pulse 40, as before, is furnished by a coil 38 which is energized by the current source 36; and the fast rising pulse 41 is furnished by a coil 39 which is energized by the current source 43. Conductive components 42' within the slurry are propelled to travel in the direction of the arrow designated A to pass from the tank 37 through an outlet 44; the usable slurry passes through an outlet 45. The force on any conductive particle 42' will be to the left or right depending on whether the wave 40 leads or lags the wave 41 in time and on the relative orientation of the coils 38 and 39. Unlike devices with no background field or a continuous background field in which the time varying field must be asymmetric to provide a unidirectional net force, the present device, though having symmetric fields, produces a unidirectional force. And the force is maximized because the instant at which the rate of change is maximal coincides with the instant at which the field is maximal. Thus, the induced eddy currents reach their maximum at a time when the magnetic field is maximum, which optimizes use of the potentially available force. The use of high intensity pulsed fields, since the background field is needed for only a brief instant of time, represents a substantial saving of power over a continuous background field. In addition, as explained before, the period or rise time of the varying field is systematically matched to the object to be acted on, in such a way as to achieve the proper skin depth or penetration depth of the induced eddy currents. The eddy current apparatus discussed here represents an improvement over the prior art in that it uses two separately controlled pulsed or periodically varying magnetic fields, one having a substantially fast rise-time to induce eddy currents of appropriate skin depth in the particular object or particle to be acted on, and the other having a substantially slow rise-time to allow a background field to penetrate into the object to be acted on. The fast rising pulse has a skin depth equal to or smaller than the characteristic dimensions of the object to be acted on in the direction of field penetration while the slow rising pulse has a skin depth substantially greater than the dimension of the object to be acted on in the direction of field penetration. The two pulsed or periodic magnetic fields are timed in such a way as to have an expedient time phase relationship with respect to each other, here shown to be $\pi/2$ radians, lead or lag so that the abrupt rise coincides with the maximum or minimum of the sine wave and an expedient spatial relationship to one another in order to produce maximum force in the desired direction.

The vibrating action can be provided by a single periodic signal, as the sinusoid 40, in the high sonic (i.e., 18,000 to 20,000 cycles per second) or ultrasonic range. To be effective, the frequency of the magnetic signal must be high enough to provide a skin depth ζ that is equal to or smaller than the characteristic dimensions of the wool fibers in the direction of field penetration; the skin depth, as is known to workers in this art (see Radio Engineers' Handbook, Terman, First Edition, McGraw-Hill Company, Inc., 1943, pages 34—35) being found in the following relationship:

$$B_x = B_0 e^{-x/\zeta},$$

where B_0 is the intensity of the eddy-current inducing mag-

netic field at the surface of a fiber or other material, and B_x is the attenuated intensity (amplitude) of this field measured at a distance of penetration x into said fiber. It is clear from the above expression that in penetrating into said material, the magnetic field is attenuated exponentially at such a rate that it will have decreased to $1/e$ its initial intensity at a penetration depth of ζ , which is customarily called the "skin depth". This skin depth is inversely proportional to the square root of conductivity κ of the material and the square root of the frequency f of the alternating magnetic field B_0 :

$$\delta \sim \frac{1}{\sqrt{\kappa \cdot f}}$$

The attenuation of this field as it penetrates into the conducting material is caused by induced eddy currents, and it is the intended purpose of said alternating field to induce such eddy currents which will react to produce a force to vibrate the material at the frequency of the eddy-current inducing field.

I claim:

1. A magnetic separator for removing colloidal and subcolloidal ceramic magnetic components and paramagnetic components from a fluid carrier comprising, in combination, a substantial volume of ferromagnetic corrosion resistant wool material having a plurality of paths therethrough along which the carrier and components can travel to effect intimate contact between the carrier and said wool, a coil wound about the wool material and adapted to be connected to a source of electric current to produce a background field within the volume occupied by the wool material of an intensity of at least an average strength of 12,000 gauss, the 12,000 gauss field being substantially stronger than that required to magnetize the magnetic wool material to saturation throughout said volume and of sufficient intensity substantially to magnetize ceramic magnetic components and paramagnetic components in the carrier such that said components are subjected simultaneously to the background field and a strong magnetic field gradient in the vicinity of the magnetic wool material, said background field and field gradient being sufficiently high in relation to the particle size of the components to attract and retain said components, a source of electric potential connected to energize the coil and adapted to be disconnected to allow flushing of the components from the wool material, and eddy-current means including a further source of electric potential connected to introduce an AC magnetic field having a skin depth that is less than the characteristic dimensions of the wool fibers in the direction of field penetration to provide vibratory action during the flushing, the frequency of the eddy-current field being at least in the upper sonic range of the order of 18,000 to 20,000 cycles per second and up.

2. A magnetic separator as claimed in claim 1 that includes a further coil wrapped about the wool material and in which the further source is an AC source of electric current connected to said further coil to produce upon energization the eddy current field.

3. A magnetic separator as claimed in claim 1 in which copper wool is mixed with the magnetic wool fibers to increase the intensity of vibration.

4. Apparatus as claimed in claim 1 in which a plurality of perforated equipotential plates of magnetic-type stainless steel are disposed at axially separated regions in the wool material and within said coil to ensure uniform flow of the carrier through the wool material and uniform distribution of magnetic flux in the wool material.