Sept. 23, 1941. R. H. STEARNS 2,256,728

MAGNETIC SEPARATOR

Filed July 25, 1938 4 Sheets-Sheet 1

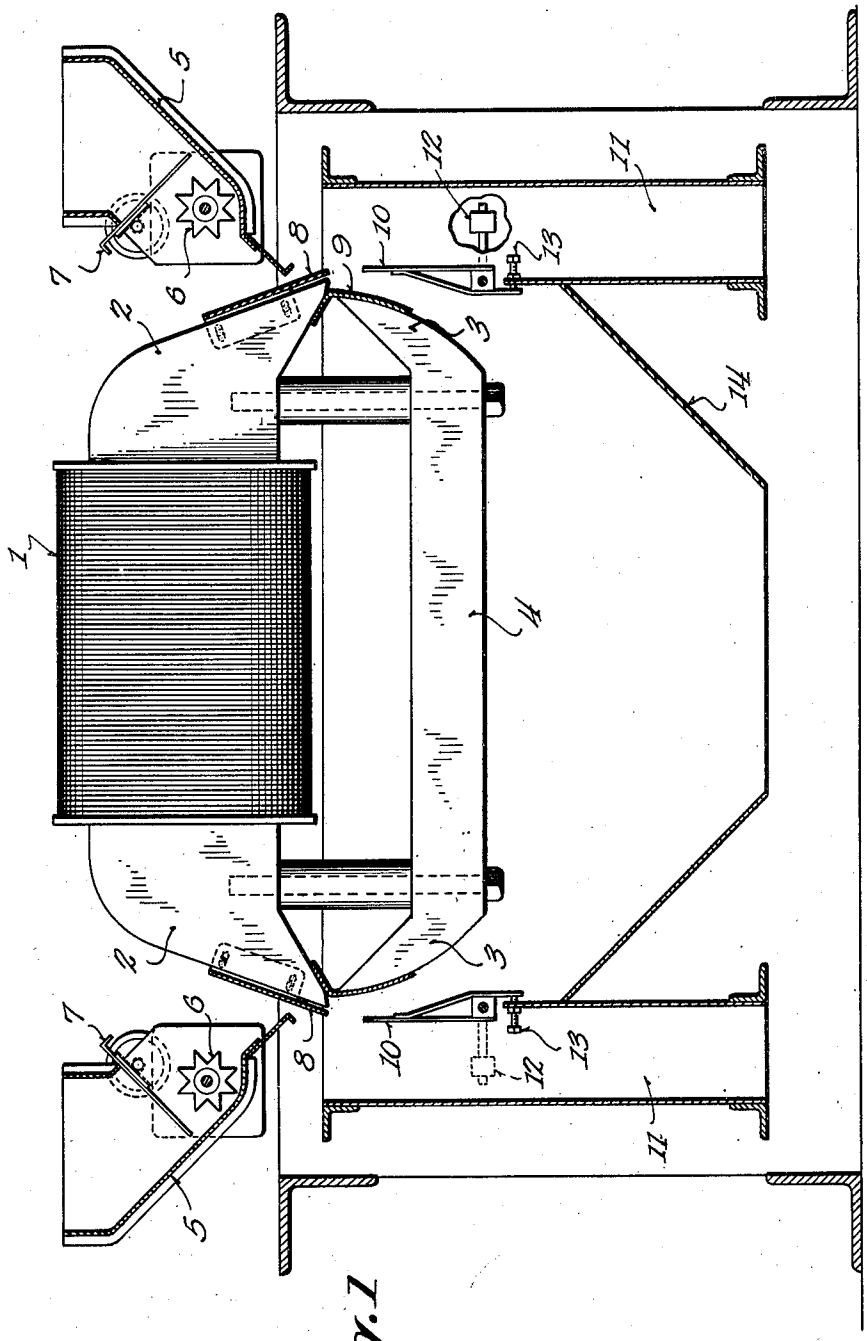


Fig. 1

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MAGNETIC SEPARATOR

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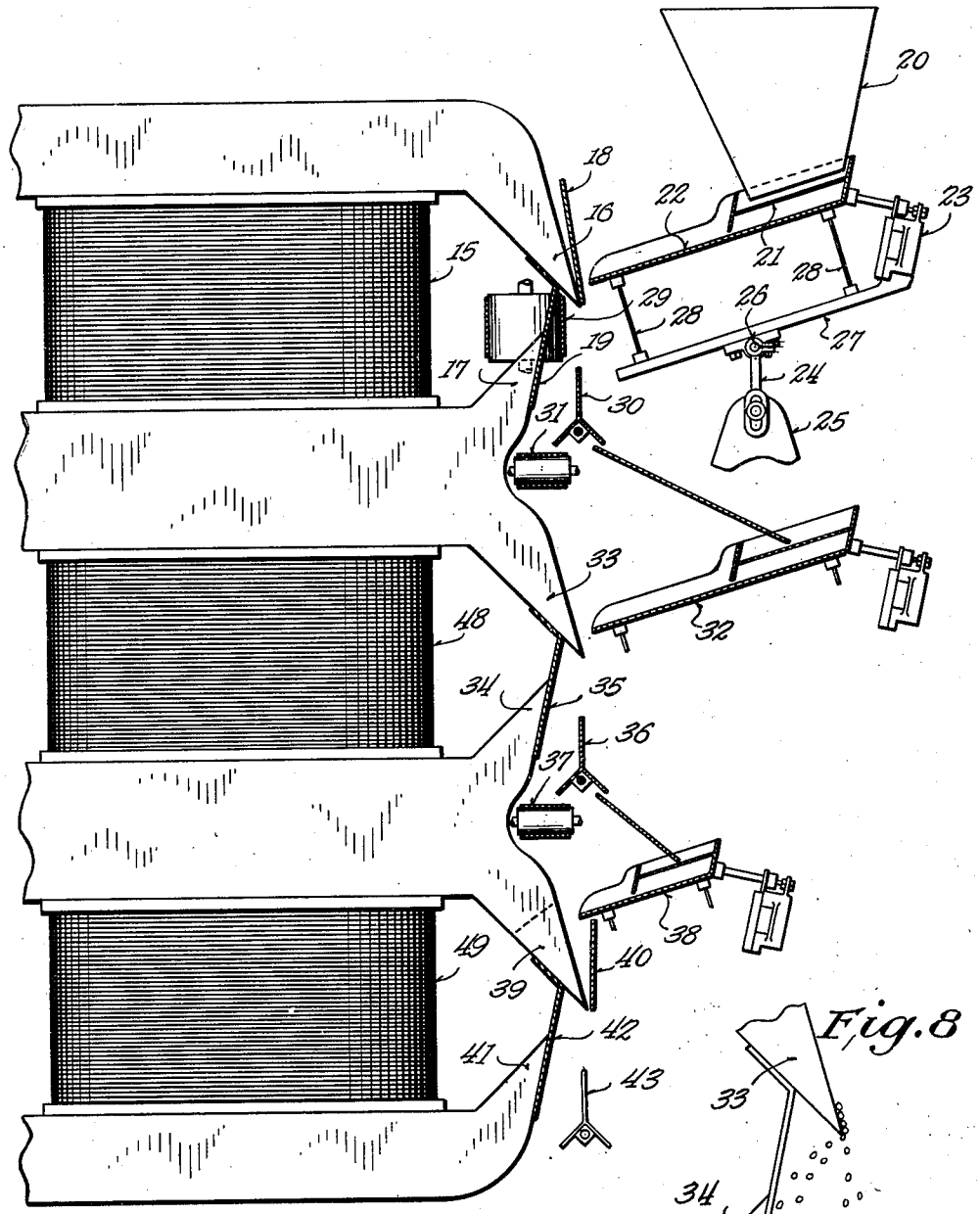


Fig. 2

Fig. 8

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MAGNETIC SEPARATOR

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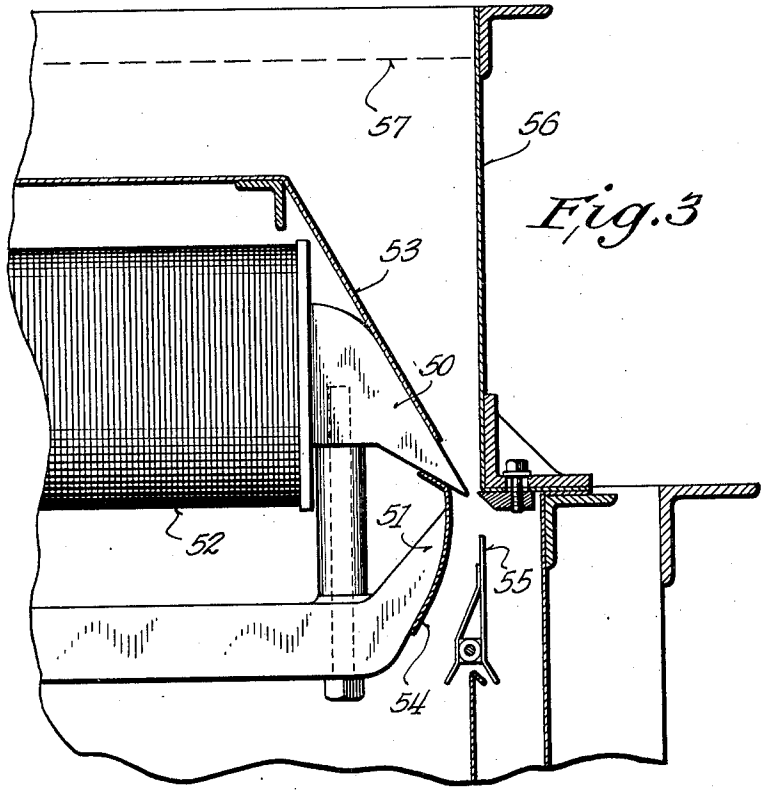
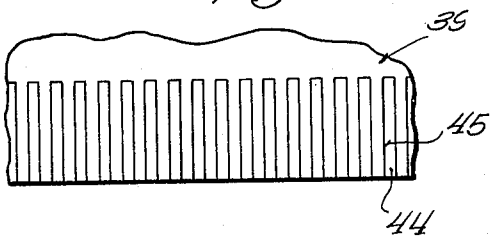


Fig. 3

Fig. 4



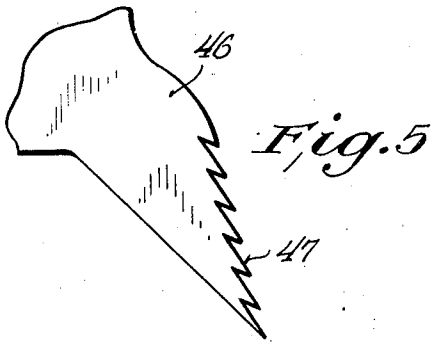


Fig. 5

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MAGNETIC SEPARATOR

Filed July 25, 1938 4 Sheets-Sheet 4

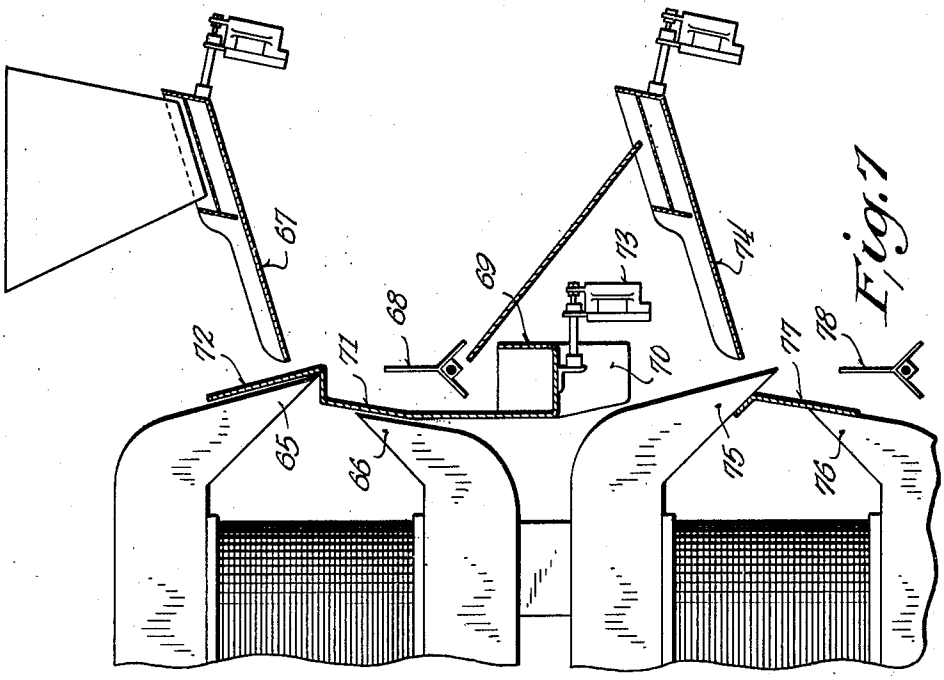


Fig. 7

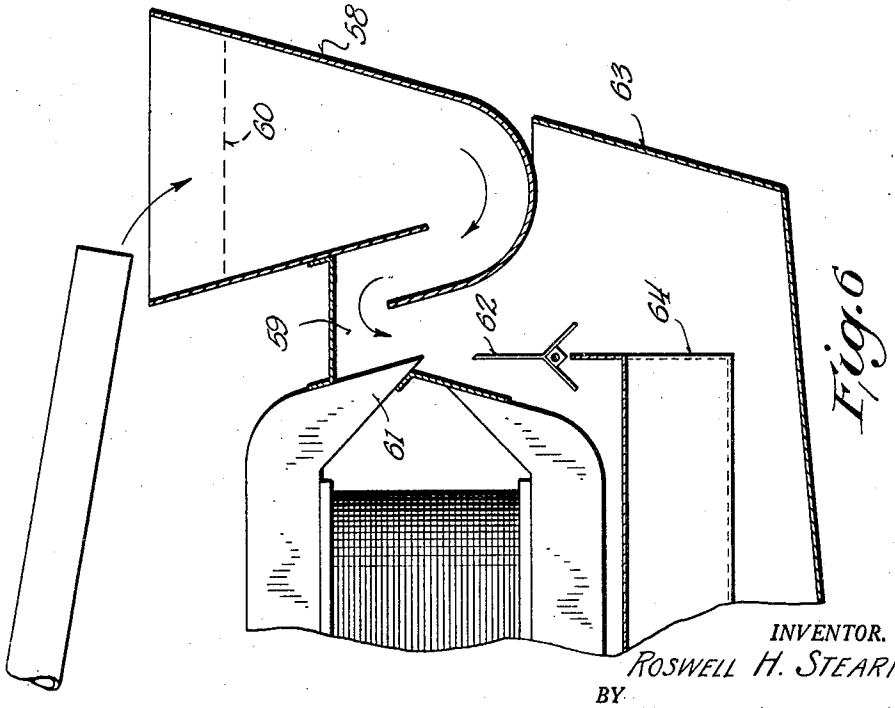


Fig. 6

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Patented Sept. 23, 1941 2,256,728

UNITED STATES PATENT OFFICE

2,256,728

MAGNETIC SEPARATOR

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Application July 25, 1938, Serial No. 221,062

4 Claims. (Cl. 209—223)

This invention relates to magnetic separators.

Objects of this invention are to provide a magnetic material, which will carry this separation which will effectively separate magnetic material having a high reluctance from non-magnetic material, which will carry this separation to a remarkably high degree of purification of the non-magnetic material, and which wastes only a very small amount of the non-magnetic material during the separation.

In separating magnetic material which has a high reluctance from non-magnetic material, it has been found that a certain period of time is required before the high reluctance magnetic material is magnetized.

This invention has for its further object to provide a magnetic separator for carrying out the separation, in which a pre-magnetizing of the magnetic material takes place while the material is in the zone of direct and intimate influence of a pole of the primary magnet, the material thereafter falling or moving from the primary magnet and the pre-magnetized material being diverted during its fall by another pole of the primary magnet, the magnetic material itself being pre-magnetized and having a sufficient interval allowed to overcome the time lag during this pre-magnetization while under the direct influence of a primary pole of the magnet, the other primary pole of the magnet merely serving as a diverting means to divert the pre-magnetized magnetic material from the non-magnetic material so that materials can be handled although they have a very high degree of reluctance and so that a very effective separation can be had.

Further objects are to provide a magnetic separator in which the primary magnet, as distinguished from a secondary inductively magnetized member, acts directly on the material, in which there is no moving part for carrying the material across at least one pole of the primary magnet and across the gap between the poles of the primary magnet, but in which the material itself feeds under the influence of gravity for instance and pushes other particles which have become pre-magnetized and adherent to the upper pole structure from said upper pole structure, so that such pre-magnetized material can thereafter pass or fall across the gap between the poles of the primary magnet, the oncoming material itself constituting the means for insuring the pushing of the pre-magnetized material across the pole face and from the pole face of one of the poles of the primary magnet, and the lower pole acting as the diverting means for diverting the pre-magnetized material out of the path of the non-magnetic material.

In greater detail, further objects of this invention are to provide a magnetic separator in which the means which the material contacts is stationary, in which in certain forms of the invention the oncoming material from the material feeding means is fed against a non-magnetic shield at the upper pole face or else is fed directly against the bare face of the upper pole, in which the material is caused to dwell or remain a period of time in the magnetic zone so as to allow time for the high reluctance material to become pre-magnetized, in which this dwell is obtained in a very simple manner as, for example, by feeding the material towards the pole tip of the upper pole of the magnet and causing the material to change its direction of flow at an angle to the direction in which it was initially fed to the pole tip or pole face, the material practically coming to a state of rest between its substantially horizontal travel into contact with the pole tip or pole tip structure and its subsequent downward travel along the pole tip or pole tip structure.

Further objects are to provide a magnetic separator which will separate materials having a high reluctance from non-magnetic materials, which will separate materials which have the same magnetic permeability but have different densities and which will separate material which have the same density but different permeability, and specifically to provide a machine which is so made that it may be adjusted or designed for any of these several different requirements in the magnetic separation of materials.

In certain forms of the invention further objects are to provide a series of successive separating fields or magnetic zones where the high reluctance material may be acted on, in which the relative spacing of the material from the adjacent pole of the primary magnet gradually decreases from zone to zone to provide for the successively increasing magnetization of the magnetic particles, and in which the dwell or the time that the material is held or retained in a magnetic zone is greater for the last separating field than for the first separating field to thus further increase the magnetization of the feebly magnetic particles at the last separating field.

Further objects are to provide a magnetic separator which will operate successively upon a mixture of non-magnetic material with magnetic material composed of a mixture of magnectic material of different degrees of reluctance, provision being made for removing the major

part of the magnetic material at the early stage of passing through the separator and thereafter increasing the pre-magnetization of the less magnetic material at adjacent or successively adjacent magnetic zones or separating fields.

Further objects are to provide a magnetic separator in which a very high flux concentration is obtained, in which a pointed pole tip is provided, such pointed pole tip being so formed that it affords a multitude of highly concentrated flux zones at the pole tip itself and along the face thereof so that a very high flux concentration, and consequently a very effective pre-magnetization even of very highly reluctant magnetic material is obtained.

Further objects are to provide a magnetic separator for separating magnetic material of high reluctance from non-magnetic material which will effect this separation either when starting with a small fraction of one percent of magnetic material or when a relatively large percent of magnetic material is initially present, and which will produce a final separation of a very high degree.

Embodiments of the invention are shown in the accompanying drawings, in which the several views show different forms of separators or portions thereof in a more or less diagrammatic manner.

Figure 1 is a side elevation of a separator, with parts broken away and with parts in section.

Figure 2 is a fragmentary view showing a portion of a multiple stage separator.

Figure 3 is a view showing a further form of separator for separatng materials while they are suspended in a liquid.

Figure 4 is a fragmentary face view of a pole tip showing one form that the pole tips may take.

Figure 5 is a fragmentary side view showing a further form of pole tip.

Figure 6 is a view showing a further form of separator employing a liquid.

Figure 7 shows a further form of separator.

Figure 8 is an enlarged fragmentary view showing the extreme end of adjacent pole tips and the manner in which the magnetic particles are separated from the non-magnetic particles.

In Figure 1, one form of separator has been shown as comprising the magnet coil 1, the upper poles 2, the lower poles 3, and the lower yoke 4. The position of the coil and the construction of the field frame can be varied provided the primary poles are the means for directly effecting the separation of the magnetic from the non-magnetic particles. In the form shown, two feeding means, which may comprise the hoppers 5, the star feed wheels 6 and the feed regulating members 7, are employed and are located on opposite sides of the magnet unit. The material may be fed in other ways, as will be apparent when other forms of the invention are described.

The mixed material, consisting of the high reluctance magnetic material and the non-magnetic material, is fed to the hoppers from any suitable source and is fed in a uniform manner into direct contact with the upper pole structure.

This upper pole structure in each instance includes at least the upper pole 2 but, in the form shown in Figure 1, also includes a non-magnetic plate 8 or shield which is adjustably carried by the upper pole and forms a portion of the upper pole structure. This shield may be spaced further from or closer to the pole, depending upon the particular material that is to be handled by the separator. The lower poles 3 are provided with non-magnetic shields 9 which extend upwardly to the under face of the upper poles. Below the poles, dividing members 10 are positioned and these members may, in accordance with the usual practice, be so made that they will drop outwardly and close the discharge chutes 11 for the non-magnetic material in the event of interruption of the current which is supplied the coil 1. Any suitable means may be used to accomplish this result. For instance, the dividing members 10 may be weighted, as shown at 12, and are adapted to be drawn against the influence of the weight into their upright position, as shown, whenever the magnet is energized due to the fact that a part at least of these dividing members is formed of magnetic material. Any suitable adjustable means, for example the screws 13, may be provided for determining the operative position of the dividing members 10.

The magnetic material falls into the hopper 14 and is discharged therefrom.

The separator is adapted to handle a mixture of non-magnetic material and magnetic material of high reluctance. This composite material may be either relatively coarse or extremely fine and any suitable means for feeding it into contact with the upper pole structure may be employed. The upper magnet pole acts as a pre-magnetizing means and it is to be noted that the angle at which the material is fed to the pole structure is such that the material comes substantially to rest at the instant it changes from its direction of feed against the pole structure to its direction downwardly along the face of the pole structure. The passage of the material over the pole structure is therefore delayed and a sufficient time is allowed to elapse to adequately pre-magnetize the high reluctance magnetic material. Thereafter, as this material drops from the lower edge of the upper pole structure, the lower magnet pole acts solely as a deflecting means for the magnetic material and deflects such material out of the line of fall of the non-magnetic material. The non-magnetic shield 9 for the lower pole keeps the magnetic material from adhering to the lower pole. This shield, of course, may be carried downwardly as far as desired.

It is to be noted further that there are no moving parts adjacent the magnet poles but that any material that tends to cling to the upper pole structure during the pre-magnetizing period is pushed downwardly by the oncoming material itself under the influence of gravity so that the oncoming material pushes or sweeps any material that tends to cling downwardly along the face of the upper pole structure. It is obvious that the shielding means 8 could extend around under the tip of the upper magnet pole.

It is to be noted that the magnet poles are so shaped as to secure an extremely intense concentration of flux at the tips of the poles and also it is to be noted that the feeding means may be adjusted towards or from the pole face or up or down with respect to the pole face, as has been illustrated for other forms of the invention.

The invention may take other forms. For example as shown in Figure 2, a plurality of magnet units have been shown so that the material may be successively operated upon by these different units. The first unit of the separator may comprise the energizing coil 15 and the upper and lower magnet poles 16 and 17. The upper pole structure includes the non-magnetic

shield 18 which may be adjustable, as previously described, and the lower pole structure includes the lower non-magnetic shield 19.

The material is fed from the hopper 20 onto the screen 21 of the vibrating feeder 22, such feeder being vibrated in any suitable manner, as by means of the vibrating means 23 of the conventional construction. Each of the feeding means shown in Figure 2 is adjustable either upwardly or downwardly and towards or from the shield plate. Also the angle at which they are set may be adjusted.

The adjustment for each of the feeding means shown in Figure 2 has been illustrated for the upper feeder, but it is to be understood that each of the feeding means is similarly adjustable. Any means may be provided for effecting this adjustment. For instance, suitable slotted links 24 may be locked to a stationary portion of the machine indicated at 25 and may be clamped to a rod 26 rigidly carried by the plate 27, leaf springs 28 being rigidly joined at their lower ends to the plate and at the upper ends to the feeder 22. The plate 27 carries the vibrating means 23 so that the adjustment of the feeder and vibrator is made simultaneously. It is obvious that the device may be rocked towards or from the upper pole structure or may be raised or lowered with respect to it, or its angle of feed may be varied depending upon the particular materials that are to be separated.

Similar feeding means are provided for the successive poles.

It is to be noted that a transverse discharge belt 29, preferably of canvas or other rough material, is provided adjacent the gap between the upper and lower magnet poles 16 and 17 to carry away magnetic material that may be held in contact with the belt. A dividing member 30 is positioned below the poles and a horizontal discharge belt 31 may be provided for carrying away the magnetic material that falls inwardly of the dividing member 30.

The material from which the major portion of the magnetic material has been separated is guided downwardly to the next feeder 32 and is fed directly against the bare face of the upper magnet pole 33 of the next succeeding unit. The lower pole 34 of such unit is provided with non-magnetic shield 35. A dividing member 36 is positioned below the pole tips and a horizontal discharge belt 37 is provided for any remaining magnetic material that may be separated at this stage. The remaining material is delivered to a third feeding means 38 which feeds against the bare face of the upper pole 39 of the next separator unit. It is to be noted that a non-magnetic guiding member 40 is positioned adjacent the upper face of the pole 39 and that the material is fed between the member 40 and the face of the upper pole 39 for a purpose hereinafter to appear. The lower pole 41 of this last unit is provided with a non-magnetic shield 42 and a dividing member 43 is provided, as previously described. Any suitable means not shown may be provided for receiving the non-magnetic material and any remaining magnetic material which has been separated out by this last unit.

The operation of the separator shown in Figure 2 will now be described. This separator, similarly to the other separators of this invention, has the peculiar feature of separating the magnetic from the non-magnetic material by the direct action of the primary magnets on the material. In each of the stages, the upper pole acts as the pre-magnetizing means and the lower pole as the diverting means for diverting the pre-magnetized magnetic material.

If the untreated material were fed directly against a bare pole face, as is done for the later stages or later units of this separator, the magnetic material would cluster and cling on the bare pole face. However, a non-magnetic shield 18 has been provided for the upper magnet pole of the uppermost unit and the magnetic material has very little tendency to cling at this point. However, any magnetic material that does cling is forced along or swept downwardly by the oncoming material. It is diverted by the lower pole and the magnetic material is discharged. The remaining material from which the major part of the high reluctance magnetic material has been separated then passes into direct contact with the face of the upper pole of the next separator unit. Here the material comes into intimate contact with the bare pole face and is subjected to a very intense magnetic field.

It is well known that by having the material contact directly with the bare pole face, it is in position for maximum magnetization. If the untreated material were fed at this point, it is obvious that it would cling and cluster on this upper pole of the second unit. However, the material which arrives at this second unit has been previously purified, or, in other words, the major portion of the magnetic material has already been removed. All that is left, therefore, of impurities are those which could not be separated by the first separator. Any magnetic material, however, that tends to cling to the bare pole face is swept downwardly or dislodged by the oncoming material.

It is to be noted that an abrupt change of direction takes place for the material which passes from the feeding means to the pole face and then passes downwardly along the pole face. Thus at the time it arrives at the pole face, it is substantially stationary and thereafter changes its direction of travel. The lower pole acts as a diverting means and diverts the pre-magnetized material and allows the remaining material to pass to the last stage or unit. Here the material is still further delayed as it is crowded between the non-magnetic guiding means 40 and the bare face of the upper pole 39. The drawing has been exaggerated to show a greater spacing between the guiding plate 40 and the pole 39 than is actually used, particularly when finely ground materials are being separated. The purpose of this plate is to insure the formation of a very thin film on the pole face so that any material that has even a small speck or portion of highly reluctant magnetic material will have an opportunity to become thoroughly pre-magnetized, as its time of passage over the pole face has been increased by the construction described.

Also it is to be noted that if there is a particle that has one side only, or a fraction of its extent, composed of high reluctance magnetic material, such particle will roll or successively present its different sides for actual contact with the pole face and thus will insure the maximum pre-magnetizing action for the small speck or portion of high reluctance magnetic material that is carried by the particle. The lower pole serves, as previously described, as a diverting means for diverting the pre-magnetized magnetic material out of the line of fall of the non-magnetic material.

It is believed that reference to Figure 8 will make the operation of the device a little clearer. This figure has been shown to illustrate the poles 33 and 34 but the action of the particles is exactly the same for the other upper poles, particularly for the pole 39. The material, it will be seen, rolls or slides down the pole face and when pushed downwardly by oncoming material, the magnetic particles may even roll over the lower point of the upper pole 33 and will be diverted by the lower pole 34 out of the stream of the falling non-magnetic material. The point at which the oncoming material strikes the pole may be adjusted so that any desired effect may be produced. It has been found, for example, that, if the feed is at a point too high along the pole face, the material acquires enough velocity before it arrives at the intense magnetic zone to prevent the lower pole from diverting it sufficiently. However, by adjusting the feed to the proper point for the particular material desired, this tendency to acquire velocity is eliminated and the magnetic material slowly slides downwardly or rolls over the bare pole face, being pushed along by the oncoming material.

Various means may be employed in the construction of the upper pole 39 to increase the intensity of concentration of flux. For example as shown in Figure 4, the pole 39 may be slotted and non-magnetic material 44 may be positioned between the slots. This construction provides a multitude of sharp edges 45 or corner portions and it is well known that the concentration of flux from a magnet pole is greatest at the corner portions or sharp edges.

Additionally the upper pole may be transversely notched. For example, the pole 46 shown in Figure 5 may be provided with a series of sawtooth like portions which provide successive faces 47 along which the material slides or rolls, the material thereafter dropping to the next adjacent face and consequently being slowed up in its downward travel. Additionally, the sharp corners provided by this construction causes an intense concentration of flux at these corners. Obviously the combination of the constructions shown in Figures 4 and 5 may be readily had by providing the transverse notches 47 for the pole 39 shown in Figure 4. This construction may be employed wherever desired in any of the forms of the invention illustrated, though it is preferable to use it for the last pole 39, as shown in Figure 2, of the multiple unit separator.

It is clear that only one side of the separator shown in Figure 2 has been illustrated, the other side being a duplicate. The cores on which the successive magnet coils 15, 48 and 49 are wound provide the return paths for the magnetic flux.

The separator can be employed for liquid separation. For example as shown in Figure 3, the separator comprises the upper pole 50 and the lower pole 51 with the energizing coil 52. A shield plate 53 is provided for the upper pole and a shield plate 54 for the lower pole.

The dividing means is indicated at 55 and in each instance this dividing means may, if desired, be magnetically rocked into position and mechanically automatically rocked out of position to close the discharge chute for the non-magnetic material for any of the forms of the invention in the event of cessation of current for the magnet coil.

In the form shown in Figure 3 the upper portion of the apparatus is such as to provide a hopper like construction between the side walls 56 of the upper tank like member and the shield plates 53. The liquid level is approximately as shown at 57. The mixture of non-magnetic and magnetic material is suspended in the liquid and the liquid discharges between the walls 56 and the nose of the upper pole 50. The magnetic material comes in intimate contact with the upper pole and is pre-magnetized, the lower pole diverting such material and the water or other liquid with the material therein falling downwardly. The lower portion of the apparatus is of such size that the liquid does not collect but runs off.

A further form of liquid separator is shown in Figure 6, from which it will be seen that the material suspended in the liquid is fed to the hopper 58 which has a rounded bottom portion and a discharge portion 59. Preferably the liquid level is kept approximately as indicated at 60 in the hopper 58.

The liquid with the suspended material is caused to directly engage the upper pole face 61 of the separator and the magnetic material is diverted and is discharged on the left-hand side of the dividing member 62, the non-magnetic material passing into the receiver 63 and the magnetic material passing into the receiver 64. These receivers may have slanting bottoms. For example as shown for the receiver 63, the bottom may slant downwardly to the left and for the receiver 64 the bottom may slant away from the observer of Figure 6 to suitable discharge openings. The liquid does not fill the lower portion of the apparatus but runs downwardly out of the two receivers, carrying with it the non-magnetic and the magnetic material.

In the form of the invention shown in Figure 7 a multiple stage separator has been disclosed. The upper stage of this separator comprises the upper pole 65 and the lower pole 66. The feeding means is indicated at 67 for the upper unit and the dividing member at 68. A trough like portion as indicated at 69 is provided for the separated magnetic material and has the bottom 70 which slants downwardly and away from the separator to discharge the magnetic material.

It is to be noted that this trough like member 69 is formed in a unitary manner with the shield member 71 for the lower pole and the shield member 72 for the upper pole, the metal of which the trough like member 69 and the shield plates 71 and 72 are formed being of non-magnetic material.

Suitable vibrating means as indicated at 73 is provided for the trough like member, and it is to be noted that the vibration of the trough like member imparts vibratory motion to the shield members 71 and 72. Preferably these shield members are slightly spaced from their respective poles.

This vibrating of the shield members assists in the dislodging of any magnetic material that may tend to cling on either or both of the shields. The separated material passes to the lower feeding means 74 which discharges the separated material directly against the bare face of the upper pole 75 of the next separating unit. The lower pole 76 is provided with the non-magnetic shield plate 77 as previously described and a suitable dividing member 78 is provided below the poles of this second unit. Any number of stages could be provided.

It is to be noted that various combinations of different features of the invention can be made for the different forms which have been illus-

trated. It is not thought necessary to show all of the different features in each of the several forms. Also it is to be understood that a few only of the many forms that the invention may take have been illustrated.

It will be seen that a novel separator and a novel method of separation has been provided by this invention which will secure a remarkably high degree of separation of the high reluctance magnetic material from non-magnetic material or which may be employed to separate materials which have the same permeability but which have different densities, or, on the other hand, materials that have the same density but different permeabilities. Therefore, while the expressions "magnetic" and "non-magnetic material" are used in the claims, it is to be understood that these expressions are to be interpreted broadly enough to include separation of materials such as hereinabove described in addition to the separation of purely non-magnetic material from magnetic material.

Another advantageous feature that this invention presents is that the separator will work either with non-magnetic material having a relatively high percent of high reluctance magnetic material, or with a mixture of non-magnetic material with a very minute fraction of one percent of high reluctance magnetic material. It is clear, for instance, that when a multiple stage separator is employed, such as has been illustrated in certain forms of the invention, that if the mixture has a large amount of magnetic material, the major portion thereof will be removed at the first stage and clogging of the separator due to clinging of the material will be prevented. The next stage, which may have the material contact directly with the bare pole face as described, operates upon a mixture which has only a small fraction of magnetic material left and consequently there is no danger of clogging of the apparatus.

A further action in separation is obtained by a multiple stage treatment. For example, if material is of such nature as to require time to overcome reluctance, then fields of the required number may be used. In practice, magnetic material entering high magnetic zone of field number 1 not responding because of lack of time, will be projected to field number 2, 3, etc. The time element between fields would not be sufficient to allow complete decadence of the flux. Consequently the magnetic particles would be increasingly magnetized in passing from field to field to allow for complete separation.

The separator also will operate upon either coarse material or very finely powdered material.

In an actual test of a machine constructed in accordance with this invention having a two-stage separation, material having a small iron content of .00245% had, after separation, an iron content of only .00009%. Another test was with material which contained .00014% iron content which was reduced to .00002% in the separated material. It is, therefore, apparent, even with the very minute amount of iron represented by the above tests, that the machine is highly efficient and will greatly reduce the iron content of the material.

It is sometimes necessary to separate out material in which certain of the particles that it is wished to separate are mainly of non-magnetic material, for example a grain of sand, and in which such particle has only a trace of high reluctance magnetic material therein. For example, this particle may have only a slight amount of an iron compound showing itself as a minute discoloration on one side only of the particle, or it might have a small speck of the high reluctance magnetic material imbedded inside of the particle.

Under these conditions it is obvious that it is extremely difficult to effect the separation of these particles from the clear sand, or, in other words, from the non-magnetic material. However, with the present invention this separation can readily be made, for such particles as have been described are presented to the bare pole or bare poles of the upper magnet pole structure and are given sufficient time in direct contact with the bare faces of these intensely magnetized primary poles to allow their time lag to be overcome.

It is well known that, in magnetizing these high reluctance particles, a certain time is required for their adequate pre-magnetization. This invention is designed to provide for the handling of these materials. As has been described, such materials held in intimate contact with the bare pole of the pre-magnetizing pole are caused to slide or roll over the pole and present successive faces to the pole. Also while they are held in intimate contact with the pole, a sufficient time elapses to allow for adequate pre-magnetizing of the high reluctance minute particles that may be imbedded or carried in or carried on the surface of the particle whose main body is of non-magnetic material. After these particles have been pre-magnetized, they are pushed off of the lower or extreme tip of the pre-magnetizing pole and it often happens that these particles tend to roll over just as they leave the lower points of the pre-magnetizing poles and thus even at this point have a tendency to slightly diverge or separate from the falling stream of non-magnetic material. The lower, intensely magnetized diverting pole diverts these particles out of the stream of the falling non-magnetic particles.

Another highly important feature of this invention is that although the process of separation is continuous and not intermittent, nevertheless the particles are acted upon by the stationary primary poles and not by a moving inductively magnetized member and yet there is no possibility of clogging the separator.

While the use of a bare magnet pole for direct contact with the material to be separated has been shown as forming a later stage of a multiple separator unit, it is nevertheless to be understood that, in treating certain types of materials which have a very small amount of high reluctance magnetic material mixed with the non-magnetic material, the bare magnet pole for pre-magnetization by direct contact with the material may be employed as a complete separator unit without preceding stages, the lower pole acting, as described, as a diverting pole for diverting the pre-magnetized magnetic material.

It is to be noted that the upper face of the upper pole structure, whether it be the upper bare face of the pole or the upper face of the non-magnetic shield for the upper pole, has been shown in each of the several figures at an angle to a vertical plane not exceeding 30°. In several of the figures structure having a much sharper angle has been illustrated. It was found that with a less sharp angle than the ones shown in the drawings that there was a tendency of the

material to pile up on the upper pole and interfere with the operation of the apparatus.

Although this invention has been described in considerable detail, it is to be understood that such description is intended as illustrative rather than limiting, as the invention may be variously embodied and is to be interpreted as claimed.

I claim:

1. A continuously operating magnetic separator for differential separation of materials of different magnetic reluctance in a mixture of such materials comprising a first and a second separating unit, said first separating unit having primary pole structures past which the material is caused to continuously flow, material feeding means for continuously feeding material past said first unit, said first unit having an upper pre-magnetizing primary pole structure and a lower deflecting primary pole structure each including a magnet pole, said poles being separated by a gap with the upper pole overhanging the lower pole, said poles being formed to produce a concentrated converging field, and a stationary non-magnetic shield over both poles and over said gap so arranged that the continuously fed material contacts the shield of the upper pole, means for discharging deflected material from the first separating unit, means for conducting the remaining material to said second separating unit, said second separating unit having primary pole structures including an upper bare pre-magnetizing pole against which said remaining material is caused to impinge and over which said remaining material is caused to continuously slide, and a lower deflecting pole structure including a magnet pole and a stationary non-magnetic shield thereover, the construction and relation of the poles of said second unit being substantially the same as said first unit, the stationary non-magnetic shield of the second unit extending over the gap of said second unit, and means for receiving the deflected material separated from the remaining material discharged from said second unit, the ratio of the downward component to the lateral component of the forces acting on the material when passing each unit being sufficiently high to insure continuous passage of the material, the magnetic field through which the material passes being greater for the second unit than for the first unit.

2. A continuously operating magnetic separator for differential separation of materials of different magnetic reluctance in a mixture of such materials comprising a first and a second separating unit, said first separating unit having primary pole structures past which the material is caused to continuously flow, material feeding means for continuously feeding material past said first unit, said first unit having an upper pre-magnetizing primary pole structure and a lower deflecting primary pole structure each including a magnet pole, said poles being separated by a gap with the upper pole overhanging the lower pole, said poles being formed to produce a concentrated converging field, and a stationary non-magnetic shield over both poles and over said gap so arranged that the continuously fed material contacts the shield of the upper pole, means for discharging deflected material from the first separating unit, means for conducting the remaining material to said second separating unit, said second separating unit having primary pole structures including an upper bare pre-magnetizing pole against which said remaining material is caused to impinge and over which said remaining material is caused to continuously slide, and a lower deflecting pole structure including a magnet pole and a stationary non-magnetic shield thereover, the construction and relation of the poles of said second unit being substantially the same as said first unit, the stationary non-magnetic shield of the second unit extending over the gap of said second unit, and means for receiving the deflected material separated from the remaining material discharged from said second unit, the face of the shield for said upper pole of the first unit and the face of the bare pole of the second unit making angles with a vertical plane not exceeding approximately thirty degrees.

3. A continuously operating magnetic separator for separating magnetic material of high reluctance from non-magnetic material in a mixture of such materials comprising a series of magnetic units for separating high reluctance magnetic material from material of less permeability when a mixture of such materials is continuously passed through the separator for successive operations upon the material, each unit having an upper pre-magnetizing pole for pre-magnetizing the magnetic material in the mixture and a lower diverting pole for diverting said pre-magnetized material, said poles being spaced apart to form a gap with the upper pole overhanging the lower pole, said poles being formed to produce a concentrated converging field, each unit having stationary non-magnetic shielding means bridging the gap and covering the lower pole for preventing magnetic material from entering the gap or clinging to the lower pole, the stationary shielding means for the first unit covering the upper pole of such unit, the successive units progressively increasing in strength of magnetization in the direction of continuous travel of the material through the separator, means for conducting away the diverted magnetic material at each unit, and means for feeding the remaining material from a preceding unit to a succeeding unit, the shielding means of the upper pole of the first unit and the upper poles of successive units having slanting faces making angles with a vertical plane not exceeding approximately thirty degrees.

4. A continuously operating magnetic separator for differential separation of materials of different magnetic reluctance in a mixture of such materials comprising a first and a second separating unit, said first separating unit having primary pole structures past which the material is caused to continuously flow, material feeding means for continuously feeding material past said first unit, said first unit having an upper pre-magnetizing primary pole structure and a lower deflecting primary pole structure each including a magnet pole, said poles being separated by a gap with the upper pole overhanging the lower pole, said poles being formed to produce a concentrated converging field, and a stationary non-magnetic shield over both poles and over said gap so arranged that the continuously fed material contacts the shield of the upper pole, means for discharging deflected material from the first separating unit, means for conducting the remaining material to said second separating unit, said second separating unit having primary pole structures including an upper bare pre-magnetizing pole against which said remaining material is caused to impinge and over which said remaining material is caused to continuously slide, and a lower deflecting pole

structure including a magnet pole and a stationary non-magnetic shield thereover, the construction and relation of the poles of said second unit being substantially the same as said first unit, the stationary non-magnetic shield of the second unit extending over the gap of said second unit, and means for receiving the deflected material separated from the remaining material discharged from said second unit, the ratio of the downward component to the lateral component of the forces acting on the material when passing each unit being sufficiently high to insure continuous passage of the material, the material feeding means for the first unit and the means for conducting material to the second unit being arranged to deliver the material in a plane substantially at right angles to the face of the upper pole of the respective unit at a point closely adjacent the tip of the upper pole of the respective unit, whereby the material is caused to abruptly pause adjacent an intense portion of the field of each unit to allow time for magnetization of the magnetic portion of the material.

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