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(54) METHOD AND DEVICE FOR THE WET MAGNETIC DRESSING OF FINE-GRAINED SOLID

(71) We, KLOCKNER-HUMBOLDT-DEUTZ AKTIENGESELLSCHAFT of Deutz-Mulheimer-Strasse 111, 5 Koln 80, Federal Republic of Germany, a German Body Corporate, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The invention relates to a method for the wet magnetic dressing of fine-grained solid which is suspended in a carrying medium as a slurry. In a number of known methods, the slurry flows through an arrangement of ferromagnetic bodies, called a "matrix", which arrangement co-operates with a magnetic field, wherein those parts of the solid which exceed a certain magnetic susceptibility are retained in the matrix within the effect of the magnetic field and are removed from the matrix outside the effect of the magnetic field with the help of a washing medium. Further, the invention relates to apparatus for carrying out such a method.

Magnetic separators with high intensity magnetic fields for the wet cleaning of weakly magnetic, fine-grained minerals are required, as is well known, for the throughput of relatively large quantities of material, for example, for a range of 20 to 120 t per hour (the weight data relates to dry material).

The common feature of the mode of operation of such separators is the fact that they hold back the magnetic material in the magnetic field at a suitable place. ("Hold-back separators"). This magnetic material is transported out of the magnetic field together with the bodies to which it adheres, and is there washed out, while simultaneously the magnetic chamber is again charged with adhesion bodies which are capable of picking up more material.

For example, the Jones magnetic separator for continuous operation with high intensity magnetic field manufactured by KHD Industrieanlagen AG is known, the main feature of which is one or two soft magnetic, disc-shaped rotors with a diameter of up to approximately 3m, which are rotated in the horizontal direction between the poles of large electromagnets. The poles have the same height as the rotors and, in width take up in each case about 1/4 of the periphery. On the periphery of the rotors are mounted numerous boxes, in which are located fluted plates of soft magnetic material, which are kept at an interval of from 0.5 to 3mm distance between centres by spacers. The charging of the slurry is effected from above through the boxes. In this case magnetic particles remain stuck on the plate together with a small part of the non magnetic material.

The magnetic material is flushed by a water jet outside the pole region. After this the box is again available for refilling at the next pole region.

The period of sojourn of a magnetic particle on passing through the box, which is approximately 0.2m deep, is about 0.2 sec. This gives, on the one hand, the excellent quantitive capacity of the Jones separator, but, on the other hand, also imposes a certain limit on the retention of particles in the region of very small grain sizes.

The wet high intensity magnetic separator of the Carpco Research and Engineering Inc., corresponding to the US Patent No. 3,375,925 is also known. The separator comprises a cylindrical channel which is filled with steel balls and is rotated about a vertical axis at adjustable speed. The channel is enclosed by two magnetic poles at each of four places staggered by 90° so that a strong horizontal magnetic field, the direction of which is radial, results. The directions of adjacent magnetic fields are opposed. The balls, which are in the field region, are magnetized and so distort the field that strong gradients result. The feed of the slurry is effect vertically in the region of the four fields. It runs together with the non magnetic material through the ball packing and leaves it at the open bottom of the channel. The magnetic material is retained between the balls and, after it is rotated out of the magnetic field together with the balls, is washed out.

A disadvantage of this machine, which prevents larger throughput capacities, is the fact that the jet of the wash water on washing out the magnetic material between the balls is atomised and so loses its energy. Moreover, the balls short circuit a part of the field lines so that the field is reduced in the gaps.

There is further known a magnetic separator with high intensity magnetic fields made by Rapid Magnetic Ltd., of Birmingham (Great Britain). The latter lies between the Jones separator and the Carpco separator in operation. One or more annular channels with soft magnetic structural material are rotated between symmetrically arranged pole shoes of a magnet. The latter are so constructed that an electromagnet winding with a vertical axis of symmetry is sealed at the top and bottom by soft iron plates, and the magnetic flux is closed externally by yokes. A channel rotates between the plates and the yokes. This channel contains bevelled rods of soft magnetic material, which are arranged obliquely to the axis of rotation and parallel to the cylinder casing.

In the case of this apparatus, too, the throughput of the slurry is effected approximately from above downwardly in one of the magnetic regions, and the washing out with water is effected in the same direction within the magnetic regions. The length of travel of the slurry in the magnetic field is approximately 0.2m long, the period of sojourn of a slurry particle is, similarly to the Jones separator, approximately 0.2 sec.

Another separator, likewise operating with soft magnetic filling bodies, is the so-called carousel separator. The latter possesses a rotating disc of non magnetic material, in the outer edge of which boxes are let in around the entire periphery. Located therein is a magnetic matrix of steel wool which is packed therein as tightly as possible and takes up approximately 5% of the volume. Around this disc there is wound parallel thereto a coil which has the same height as the disc, which however has no winding to a third of its periphery downwardly. If the coil is energized, a magnetic field results, which penetrates more than half the rotating disc and thus the boxes from above downwardly. The feed of the slurry is effected from above in the magnetic field region through an opening in the magnetic yoke. The non magnetic material is drawn off downwardly.

In the case of this apparatus the particularly heavy washing out of the magnetic material from the steel wool as well as the high wear of the steel wool is disadvantageous. Under these conditions the throughput is very low, in general less than 10 t/hour. Therefore this separator is preferably used for cleaning tasks in which the concentration of the magnetic material in the feed is not high.

Finally, in addition the magnetic separator with a moving matrix in accordance with German Disclosure Document No. 2 410 001 of Magnetic Engineering Associates Inc. Cambridge, Mass., USA should be mentioned. In the case of this machine also the horizontal matrices are moved in a horizontal direction through a magnetic field extending in the same direction. The slurry flows through a magnetic field extending in the same direction. The slurry flow through the matrices from above downwardly and the matrices are washed out in the same direction.

The enumeration of so many apparatuses was necessary to show that, in the case of all these magnetic separators with high intensity magnetic fields for wet dressing, a common principle is present insofar as the slurry basically is conducted from above downwardly through a magnetic grid comprising a box with filling bodies or one comprising a bundle of rods or other ferromagnetic bodies such as balls or steel wool, and the feed and rinsing is undertaken in the same direction from above downwardly.

If, in this case, the ferromagnetic grid, as in the case of the steel wool or the steel balls, has a very tightly packed matrix, as a result the magnetic separator has excellent qualitative performance in the region of the finest magnetic particles, but the quantitative performance is completely unsatisfactory.

If, as in the case of separators equipped with relatively smooth passages, of the rotor or box type, favourable conditions for the throughflow of slurry and washing water prevail, the quantitative capacity is indeed relatively high, but such separators have limits with respect to the separating quality in the case of very fine solid particles.

From this knowledge is derived the problem of the invention which consists in improving the known magnetic separators with high intensity magnetic fields is such a way that for relatively high throughput capacities a relatively good quality separation in the fine grain region is also achieved.

According to a first aspect of the invention, there is provided a method for the wet magnetic dressing of fine-grained solid which is suspended in a carrying medium as a slurry, comprising causing the slurry to flow through a ferromagnetic matrix in a first direction while being subjected to a magnetic field, wherein those parts of the solid which exceed a certain magnetic susceptibility, are retained in the matrix and causing a washing medium to flow through the matrix in a second direction outside the magnetic fields for removal of the retained solid the two directions being substantially different and so chosen that the resistance to the throughflow of the washing medium is substantially less than the resistance to the throughflow of the slurry.

It will be seen that the slurry first flows through the matrix in one direction, and subsequently the washing medium flows in another substantially different direction.

Preferably the flow directions of, on the one hand, the slurry and on the other hand, the washing medium are approximately at right angles to each other.

In addition, preferably the direction of the force produced by the magnetic field of the slurry and of the washing agent respectively, are approximately at right angles to each other in the chamber.

According to a second aspect of the invention, there is provided a device for the wet magnetic dressing of fine grain solid which is suspended in carrying medium, comprising a ferro magnetic matrix, inlet and outlet means for the slurry arranged to pass the slurry through the matrix in a first direction, magnetic means for applying a magnetic field to the matrix while the slurry is passing therethrough and inlet and outlet means for a washing medium arranged to pass the washing medium through the matrix in a second direction, the two directions being substantially different and so chosen that the resistance to the throughflow of the washing medium is less than the resistance to the throughflow of the slurry.

A plurality of matrices may be provided which are movable approximately horizontally at right angles to the magnetic lines of force between the poles of a magnet system forming the magnetic means and wherein a device is provided within the effective region of the magnetic field to prevent slurry from being able to flow out downwardly, but outside the magnetic field opens the path for the outflow of the non-magnetic material as well as for the washing medium; from above downwardly, the matrices which are in non-rigid connection with each other, providing a channel system for the throughflow of the slurry, which channel system extends from the region of the slurry inlet means as far as the region of the washing medium outlet means.

The device for preventing the slurry from being above to flow out downwardly may comprise an advancing device for the matrices.

In an appropriate development, the advancing device for the matrices is in the form of an endless conveyor belt provided with a drive, which conveyor belt entrains the matrices on its outer side and seals the matrices, located at that time in the region of the magnetic field, on their undersides.

In this case this conveyor belt can be additionally equipped on the outer side with entrainment strips lying transversely to the direction of transport, which entrainment strips engage in corresponding recesses in the matrices.

It can be helpful for the function and the throughput that the matrices and the magnet arrangement are placed at an inclination to the horizontal.

The adjustment of the apparatus to the appropriate conditions of a certain dressing task is hereby optimally facilitated.

A matrix may comprise plates which are fluted on one side or on both sides, and which plates are arranged at an interval from each other and parallel to each other, in planes at right angles to the magnetic field, so that the profile edges of the fluting run parallel with the direction of the washing medium.

A matrix constructed in such a manner produces a strong distortion of the magnetic field, whereby correspondingly high field gradients with locally very high magnetic forces result, which act in an advantageous manner on the particles to be collected.

In an alternative development of the apparatus in accordance with the invention, an open channel of non magnetic material can be provided for the throughput of the slurry which channel extends approximately horizontally from a feed station for the slurry paraxially through the magentic field, as well as through a transport device for carrying the matrices through the channel.

In this case it is important for its function that the channel is made of corrosion resistant, wear resistant, non magnetic material, for example of chrome-nickel steel.

Furthermore it is sensible in the case of this device for the reproducible adjustment of certain operational states, if the inclination to the horizontal of the entire device with channel, magnetic field and transport devices can be adjusted.

And finally it is advantageous if the transport device has parallel towing lines of non-magnetic material with the spacing of approximately one matrix width, between which the matrices are secured in such a manner that a throughflow of the latter can take place both in the direction of the slurry and in the direction of the washing process.

The method in accordance with the invention, as well as the apparatus will be described and explained in the following with the help of exemplary embodiments shown schematically.

In the drawings:

Figure 1 shows a device in accordance with the invention, partly in section and partly in elevation;

Figure 2*a* shows another embodiment of the device; likewise partly in section and partly in elevation, while 2*b* is a perspective view of part of this embodiment;

Figure 3 shows a cross-section through the device according to Figure 2.

Figures 4 to 6 show various forms of embodiment of matrices in accordance with the invention.

Figure 7 shows a matrix in perspective view.

The magnet system 1 can be seen in Figure 1. A continuous sequence of matrices 2 is moved through the magnetic field produced by this magnet system, the lines of force of which magnetic field are at right angles to the plane of the drawing of Figure 1. These matrices are caused to be moved by an advancing device 3 in the direction of the arrow T. This device comprises a conveyor belt 4, the upper surface of which has entrainment strips 5, which are placed transversely to the direction of transport T. These strips engage in corresponding recesses 6 in the matrices 2 and in this way provide for a positive entrainment of the matrices 2. The conveyor belt 4 runs over two rollers 7 and 8, of which one, for example roller 7, serves as idler roller and 8 as drive roller. The feed station 9 for the slurry is indicated symbolically, as well as the outflow point 10 with the collecting channel 11 for the non-magnetic material, and the washing device 12 with the collecting channel 13 belonging thereto.

The function of the device shown schematically is easy to see. If the upper side 14 of the conveyor belt 4 is moved in the direction designated by the arrow T, for example at a speed of approximately 1.0m per sec., then at anytime a matrix 2 reaches the locality of the feed station 9. On passing this feed station, the intermediate spaces between the ferromagnetic bodies of the matrix are filled with slurry. The latter cannot run away downwardly, for from the region of the feed station 9 as far as the opposite end of the magnetic field 1, the matrices 2 lie tightly on the conveyor belt 4, the upper side 14 of which closes the matrices 2 from below. Together with adjacent matrices 2 to left and right, there results a continuous channel for the accommodation of the slurry which extends from the matrices at the feed station 9 through the magnet system 1 up to the outflow 10. The magnet system 1 extends longitudinally, as shown in the example according to Figure 1, in the direction of the displacement of the matrix 2. In the region of the drive roller 8, the lower closure formed for a period by the conveyor belt 9 between the feed station 9 and the drive roller 8 is opened. The matrices open downwardly and the outflow 10 of the non magnetic material is allowed. The latter is collected by the collecting channel 11. The magnetic concentrate retained within the matrix 2 is flushed out at 12 with the help of a strong water jet through the washing device and fed into the collecting channel 13. In this case the slurry flows, in accordance with the teaching of the invention, from the feed at the feed station 9 as far as the outflow 10 substantially in the direction of the movement of the matrices 2 through the latter, in which connection the profiled type plates profiled at right angles to the direction of movement, or alternatively the ferromagnetic grids with rods, present a relatively high liquid resistance to the slurry. On the other hand, however, the washing takes place approximately at right angles to the flow direction of the slurry in flow paths of least resistance along relatively short throughflow paths, and in a direction through the matrix 2 in which the flow cross section remains the same.

Due to this, the intended effect in accordance with the invention occurs namely that the slurry spends a relatively long period of sojourn in the magnet system 1, while practically unhindered, ideal flow conditions are present for a washing operation which is full of energy. With the assumed length of the magnet system 1 of, for example, 1.0m, an assumed movement speed of the matrix in the direction of the arrow T of 0.5 m/sec, as well as an assumed flow speed of the slurry, in dependence on the slope of inclination of the system, relative to the matrices likewise of 0.5 m/sec., a particle suspended in the slurry passes through the magnet system with the speed of 0.5 + 0.5 = 1.0 m/sec. The period of sojourn in this case amounts to a full second, as compared to 0.2 sec in the case of the previously described apparatuses.

After leaving the advancing device, the matrices are mutually shifted further and are deflected at deflection points 15 and 15′ and retained at the points lying therebetween outside the advancing device 3 by guides (not shown) in the track.

Another device for carrying out the method in accordance with the invention is shown in Figures 2*a* and 2*b*. From these, one can see the magnet system 20 as well as an advancing device 21 with matrices 22 secured thereto. A trough 23 in the form of a channel open upwardly extends from the feed station 24 for the slurry through the magnetic field of the magnet system 20 up to the outflow 25 for the non magnetic material. The latter arrives in the collecting channel 26 and is led away. Washing nozzles 27 are provided for washing out the magnetic concentrate, which nozzles flush out the concentrate on the shortest path, namely on the path of the least flow resistance from above downwardly and at right angles to the flow movement of the slurry into the collecting channel 26.

Figure 3 shows a transverse cross section through the apparatus at the magnetic system 20 shown in Figure 2*a*. The magnet system 20 can be seen, which comprise the soft iron yoke 29 with the poles N and S as well as the energizing coils 30 and 30′. The trough 23 is incorporated between these magnetic poles N and S so that the matrices 22, running through these poles, practically fill the entire cross section. The two draw strands 31 and 31′ of the advancing device 21 shown in Figures 2*a* and 2*b*, which is rigidly connected to the matrices, pull the latter through the trough 23, can be seen.

The entire device system according to Figure 2*a* can be placed at an inclination to the horizontal either such that a slight drop from left to right is given, as shown in the drawing, for the throughflow of the slurry, or alternatively horizontally, or if necessary, with a negative drop, that is to say in such a manner that the slurry must be conveyed upwards against the deceleration of gravity, by the tractive force of the moved matrices 22. According to which inclination to the horizontal the system has, the slurry may move together, in advance or backwards relative to the speed of advance of the matrices. By this expedient, which is made possible for the first time by the invention, an optimal adjustment can be found for the dressing, according to the concentration of the slurry, susceptibility of the material to be treated, and the fineness of the particles. By this means certain quality features in the finished product can be successfully and reproduceably set.

Figures 4 to 6 show, in each case, perspective views of the upper parts of matrices suitable to the invention. Figures 4, 5 and 6 show matrices which are made up of plates. The matrix according to Figure 4 is built up alternately from fluted plates 40 and from non fluted smooth plates 41. Transverse rods 42 hold the matrix together to form a solid structure. The throughflow direction for the slurry is given by the arrow 43, while the throughflow direction for the washing agent is from above vertically downwards.

Figure 5 shows the construction of a matrix of plates 44 which lie in parallel and are fluted on one side only.

Figure 6 shows plates which are fluted on both sides, with the exception of the end plates, as a further alternative of a matrix in accordance with the invention. The arrangement is the same in principle in the case of all three variants. The slurry flows through the packages of plates in the same direction 43, 43′, 43″ in each case; while the throughflow direction for the washing medium is to be conceived as flowing into the matrix from the top and vertically downwards.

Finally Figure 7 shows a matrix 80 which is composed of plates 81, 82, 83, 84 and 85 and so on, which are formed on opposite surfaces with a fluting. In the perspective drawing, one can clearly see, at the plate intersection points the profile lines 89, 89′ of this fluting, which are directed from above downwardly. Further the drawing shows two parts, shown broken, of the draw strands 86, 86′, which are components of an advancing device, not shown in any detail in this Figure 7, to which draw strands the matrix 80 is rigidly connected by pins 87, 87′. The trough 88 can be seen-likewise shown broken away and in perspective-within which the matrix 80 moves with the help of the draw strands 86, 86′. The direction of movement both for the matrix 80 and for the slurry within the trough is indicated by the arrow B, the direction of the washing medium by the arrow Sp, and K indicates the direction of the magnetic lines of force. All three directions are at right angles to each other.

WHAT WE CLAIM IS:-

1. A method for the wet magnetic dressing of fine-grained solid which is suspended in a carrying medium as a slurry, comprising causing the slurry to flow through a ferromagnetic matrix in a first direction while being subjected to a magnetic field, wherein those parts of the solid which exceed a certain magnetic susceptibility, are retained in the matrix and causing a washing medium to flow through the matrix in a second direction outside the magnetic field for removal of the retained solid, the two directions being substantially different and so chosen that the resistance to the throughflow of the washing medium is subtantially less than the resistance to the throughflow of the slurry.

2. A method according to claim 1, wherein the flow directions of the slurry and the washing medium are approximately at right angles to each other.

3. A method according to claim 1 or 2, wherein the direction of the force produced by the magnetic field, the flow direction of the slurry and of the washing agent are approximately at right angles to each other in space.

4. A method as claimed in any one of claims 1 to 3, wherein the matrix is moved along the same path as the flow of the slurry.

5. A device for the wet magnetic dressing of fine grain solid which is suspended in a carrying medium, comprising a ferromagnetic matrix, inlet and outlet means for the slurry arranged to pass the slurry through the matrix in a first direction, magnetic means for applying a magnetic field to the matrix while the slurry is passing therethrough and inlet and outlet means for a washing medium arranged to pass the washing medium through the matrix in a second direction, the two directions being substantially different and so chosen that the resistance to the

throughflow of the washing medium is less than the resistance to the throughflow of the slurry.

6. A device according to claim 5 wherein a plurality of matrices are provided which are movable approximately horizontally at right angles to the magnetic lines of force between the poles of a magnet system forming the magnetic means and wherein a device is provided within the effective region of the magnetic field to prevent slurry from being able to flow out downwardly, but outside the magnetic field opens the path for the outflow of the non-magnetic material as well as for the washing medium from above downwardly, the matrices which are in non-rigid connection with each other, provided a channel system for the throughflow of the slurry, which channel system extends from the region of the slurry inlet means as far as the region of the washing medium outlet means.

7. A device according to claim 6, wherein, the device for preventing the slurry from being able to flow out downwardly comprises an advancing device for the matrices.

8. A device according to claim 7, wherein the advancing device for the matrices comprises an endless conveyor belt provided with a drive, which conveyor belt entrains the matrices at its outer side and seals the matrices which are located at any time in the region of the magnetic field on their underside.

9. A device according to claim 8, wherein the conveyor belt is equipped on the outer side with entrainment strips which lie transversely to the transport direction, which strips engage in corresponding recesses of the matrices.

10. A device according to any one of claims 4 to 7, characterised in that the matrices together with the magnet arrangement are positioned at an inclination to the horizontal.

11. A device according to any one of claims 6 to 10, wherein each matrix comprises are spaced and parallel to each other, in planes which are at right angles to the magnetic field in such a manner that the projecting edges of the fluting extend parallel to the direction of flow of the washing medium.

12. A device according to any one of the claims 6 to 11, wherein an open channel of non-magnetic material is provided for the throughput of the slurry which extends approximately horizontally from inlet means for the slurry through the magnetic field, the matrices being conveyed through the channel.

13. A device according to claim 12, wherein the channel is made of corrosion resistant wear resistant, non-magnetic material.

14. A device according to claim 12 or 13, wherein the channel is made of chrome-nickel steel.

15. A device according to claim 13, 14 or 15, wherein means are provided for enabling the entire device with channel, magnetic field and transport device to be set at an inclination to the horizontal.

16. A device according to any one of the claims 12 to 15, wherein the transport device has parallel draw strands of non magnetic material with an interval of approximately one matrix width, between which the matrices are secured in such a manner that a throughflow of the same can take place both in the direction of the slurry and in the direction washing medium.

17. A method for wet magnetic dressing of a granular material supplied as a slurry substantially as described herein with reference to the drawings.

18. Apparatus for wet magnetic dressing of a granular material supplied as a slurry, substantially as described herein with reference to the drawings.

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FIG. 1

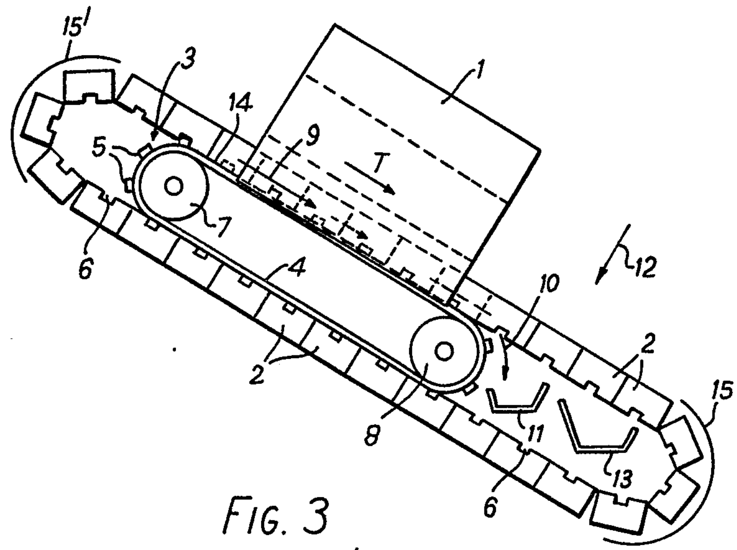
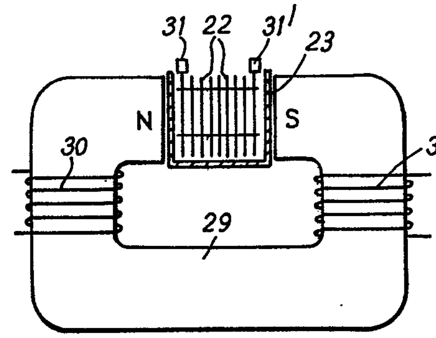


FIG. 3



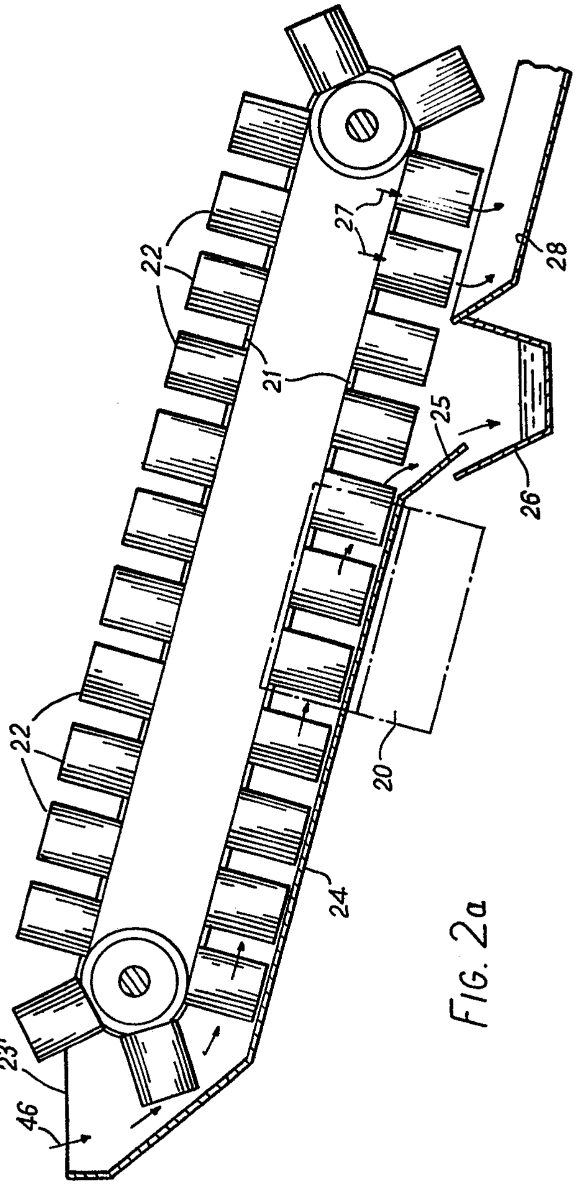


FIG. 2a

1559338 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

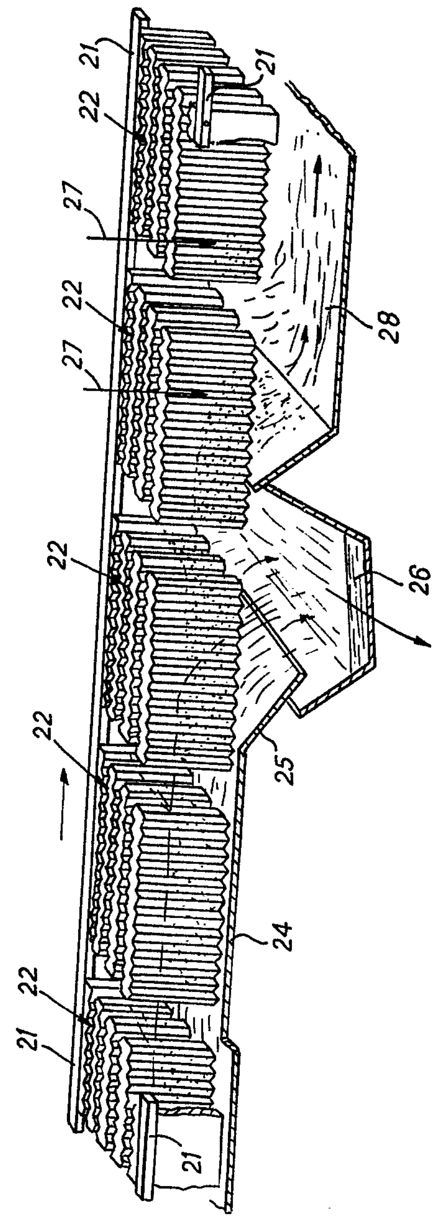


FIG. 2b

FIG. 4

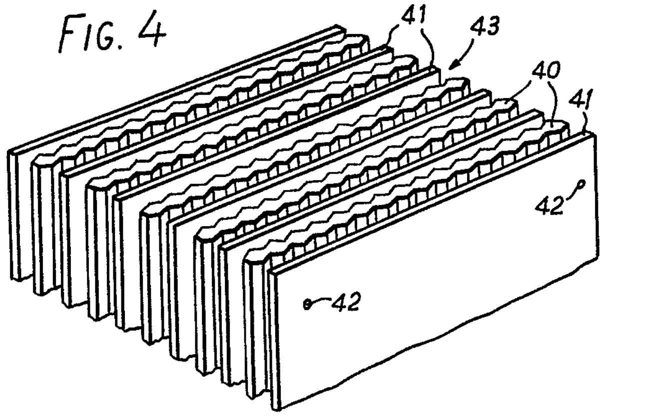


FIG. 5

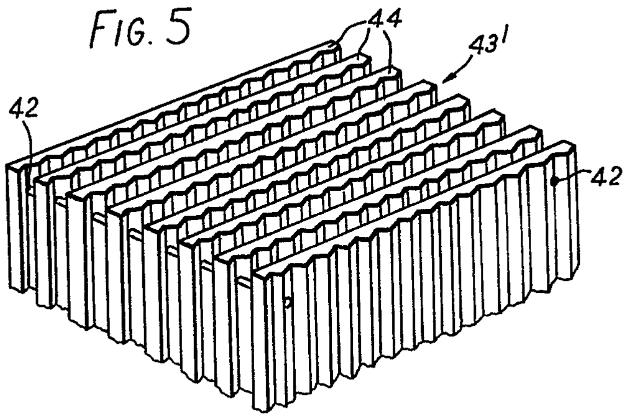
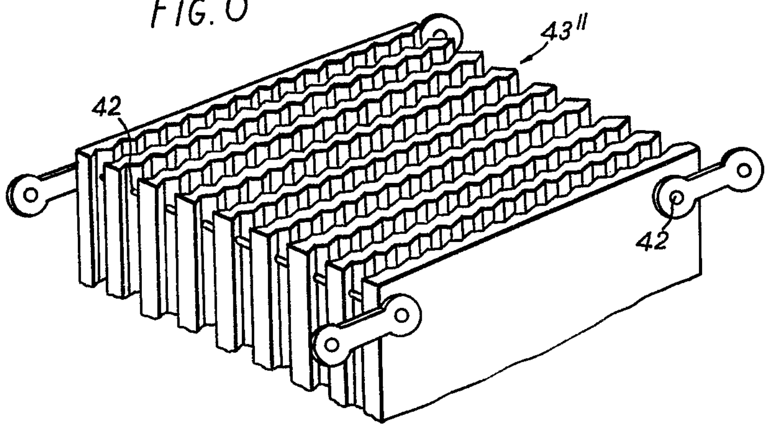


FIG. 6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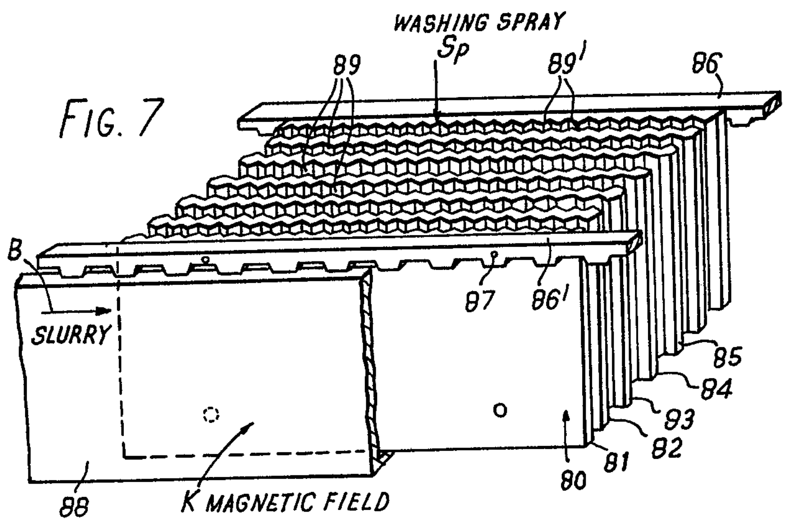
42
42

FIG. 7


WASHING SPRAY
Sp
89
89'
86
B
SLURRY
87
86'
85
84
83
82
81
80
88
K MAGNETIC FIELD