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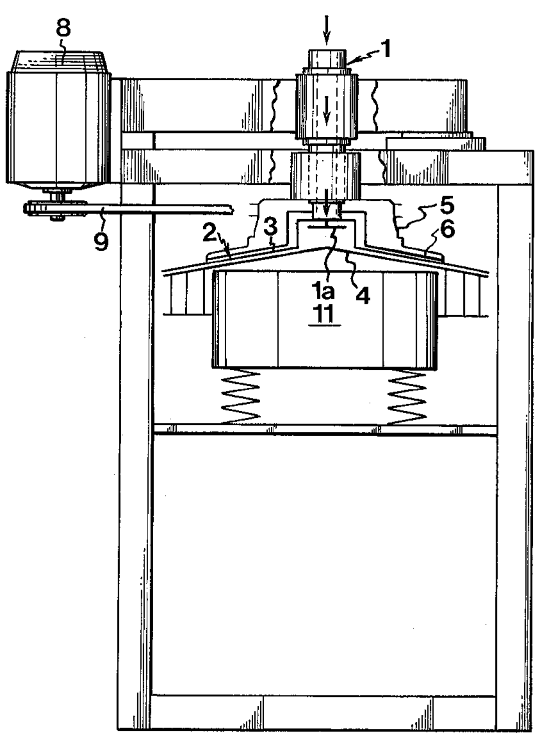
# (54) Method and device for separating particulate matter.

(57) The invention relates to a method and a device for separating at least one particulate, electrically conductive, non-magnetic material which is included as a constituent or as constituents in a mixture, the separation being performed in a space permeable to magnetic waves, and the mixture in the space is subjected to an alternating magnetic field generated by a rotating element equipped with magnets. According to the invention, the particles are thrown up from the bottom of the space in a direction opposite to the direction of rotation of the magnet-equipped element and corresponding to a throwing angle $\alpha$ relative to the horizontal plane, $0 < \alpha < 90$, and the magnet-equipped element is disposed above the separation space.

The device comprises a separation space (2, 3, 4) permeable to magnetic waves, means (5) for generating an alternating magnetic field, and feeding and discharging means. The means (5) is a rotating element equipped with magnets, and a throwing apparatus (11) is provided for throwing up the particles in the separation space in a direction opposite to the direction of rotation of the means (5), which is disposed above the separation space.

FIG.1



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The present invention generally relates to dry separation of particles, and in particular to a method and a device for separating at least one particulate, electrically conductive, non-magnetic material included as a constituent or as constituents in a mixture.

In recent years, the recovery of valuable materials, especially metals or metal alloys, such as brass, copper, lead and aluminium, has become a major concern, primarily for reasons of economy and environmental control. One example of a field where such recovery has been constantly extended is that of data scrap. The reason for an intensive activity in this particular field is of course the growing insight into the economic values, especially of the metals which are recoverable from such scrap. The invention is applicable particularly to the data scrap field, but is not restricted thereto.

Today's separation techniques rely on some property of the different materials to be separated. Various devices are known in the art for separating magnetic materials from non-magnetic ones, where magnetism is utilised, e.g. for "sucking" up the magnetic material. There are also devices which rely on a difference in friction coefficient or density, and in which a mechanical motion, such as vibration and rotation, affects the mixture to be separated, thus producing a certain degree of separation.

Another technique for separating non-magnetic materials is disclosed in US-A-4,313,543, and involves a device for separating electrically conductive particles of varying sizes from particles which are not electrically conductive. A stream of particles is applied to the upper part of a sloped surface, and juxtaposed, oppositely directed magnetic fields of varying width are established adjacent the particle stream. When the particles pass through the magnetic fields located underneath the particles, forces are developed which act on the electrically conductive particles and so, these particles are deflected from the stream so as to bring about particle separation.

EP-0,307,250 A2 describes a method for separating a mixture of flat metal alloy particles. This separation method relies on differences in particle size and differences in electrical conductivity or density. This publication states, by way of example, the use of a vibrating separator table together with a rapidly alternating magnetic field which in electrically conductive particles applied to the table induces eddy currents causing the particles to be deflected to a varying extent. The magnetic field is provided underneath the particles (cf. Fig. 3).

The prior-art separation techniques described above provide a degree of separation which is insufficient in many applications, and suffer from a number of drawbacks. The major drawback, especially reflected in the above-mentioned European patent publication where the magnetic field is located below the particles, is that the greatest magnetic force (magnetic flux density) is on the underside of the particles, this bringing about a rotational direction of the electrically conductive particles that is oppositely directed to the desired transport direction or direction of separation, which adversely affects the separation.

The present invention overcomes the drawbacks of prior-art separation techniques, and one object thereof is to provide such a high degree of separation that the separated products, without further processing or purification, can be used as raw materials in refining processes with high demands on the purity of the raw materials.

By subjecting, in accordance with the invention, the electrically conductive, non-magnetic particles to a rotating, alternating magnetic field inducing electric eddy currents in the particles while these are being repeatedly thrown up into the field in a direction opposite to the direction of rotation of the magnets generating the magnetic field, at a throwing angle $\alpha$ relative to the horizontal plane, where $0 < \alpha < 90°$, and by arranging the rotary means above the particles, a very high degree of separation of about 98% or more is achieved.

The invention thus relates to a method and a device for separating at least one particulate, electrically conductive, non-magnetic material included as a constituent or as constituents in a mixture, as recited in the preambles of the respective independent claims, the method and the device having the features appearing from the characterising clauses of the respective independent claims.

Preferred embodiments of the device for carrying out the method according to the invention will be described in more detail hereinbelow with reference to the accompanying drawings, in which

Fig. 1 is a schematic front view, with certain parts broken away, of a preferred embodiment of the device,

Fig. 2 is a view similar to Fig. 1, illustrating another preferred embodiment of the device,

Fig. 3 shows a separation means forming part of the device, and

Figs 4A-4C are diagrams further elucidating the invention.

Referring now to the drawings, the device shown in Fig. 1 has a feeding unit 1 including a rotary disc 1a for supplying particles to a separation means 2 having a cover 3 and a bottom 4. The cover 3 has a central opening in which the feeding unit 1 opens. Thus, the separation means is closed, with the exception of the central opening and slots provided at the periphery of the separation means. The separation means 2 is sloping downwards, counting from the centre, which implies a movement of the particles towards the periphery of the separation means. Further, the device includes a means 5 for generating a magnetic field. In the embodiment shown in Fig. 1, the means

5 has an upper hood 6, whose inside is equipped with a plurality of magnets (not shown). The separation means 2 is disposed underneath the means 5. The hood 6 is rotated by means of a motor 8 (via a transmission 9). The separation means 2 is of plastic, its cover and bottom having a thickness of about 2-5 mm. Thus, the magnetic field will penetrate the separating means 2, thus affecting the particles present therein. An apparatus 11 is adapted to throw up the particles into the magnetic field. The throwing apparatus 11, illustrated only schematically, is of conventional type and comprises, according to a preferred embodiment, a box-like structure whose top face forms the bottom 4 of the separation means 2. The box-like structure, being suspended on leaf springs, is set in motion, more specifically in a combined rotary/throwing motion (restrained by the leaf springs) which can be defined as a helical motion, such that the particles are repeatedly thrown up into the magnetic field, i.e. each particle impinges on the bottom several times. This motion can be achieved by means of a piston and cylinder assembly, an eccentric mechanism or the like. The throwing apparatus 11 is so designed that the particles are thrown up into the magnetic field in a direction opposite to the direction of rotation of the hood 6. The throwing height and the throwing angle are dependent on the particle material, particle type and particle size. Generally, however, the throwing height varies from a few millimetres to several centimetres, and the throwing angle relative to the horizontal plane is greater than zero and less than 90°.

Fig. 2 illustrates another preferred embodiment in which two magnetic fields are provided, namely a first (represented by the hood 6 internally equipped with magnets) which is disposed above the separation means 2, and a second (represented by the hood 7 internally equipped with magnets) which is disposed below the separation means 2. The hood 7 is driven by a motor 8 (via a transmission 9), the hood 6 being entrained in the rotary movement as a result of the magnetic coupling between the hoods. This embodiment is best suited for separating particles of a relatively small particle size, e.g. 1-2 mm, whereas the embodiment in Fig. 1 is best suited for separating particles of a larger particle size, e.g. 2-10 mm. The purpose of arranging a lower magnetic field combined with the upper one merely is to intensify the magnetic field.

Fig. 3 illustrates the separation means 2 in more detail. The cover 3 (broken apart in Fig. 3) and the bottom 4 are interconnected by radial webs 12 dividing the separation means into sections 13. Deflecting members in the form of flanges 14 vertically projecting from the bottom extend partially along imaginary centre radii in each section 13. In the embodiment shown in Fig. 3, each section 13 is divided into two chambers 15, 16. Along the periphery of the separation means 2 there are provided collecting means (not shown) in the form of pockets, one for each chamber, from which tubes extend, opening into two large-size containers, namely one container for the tubes coming from the chambers 15 of the sections 13, and another for the tubes coming from the chambers 16 of the sections 13. According to other embodiments of the inventive device, each section may of course be divided into more than two chambers. Similarly, an optional number of tubes can be arranged which open into an optional number of large-size containers.

By providing, in accordance with the invention, a magnetic field above the particles, as in the embodiment shown in Fig. 1, the force acting on each particle because of the magnetic field becomes greater on the upper side of the particle than on the underside as a result of the magnetic field density distribution in the space concerned, which in turn means that to each particle in the field is imparted a rotary movement coinciding with the desired direction of movement of the particle (transport direction). This is illustrated in Fig. 4A. Should, however, the magnetic field be arranged only below the particles (cf. European Patent Publication 307,250 mentioned above), the particles would have a direction of movement opposite to the transport direction. This is illustrated more specifically in Fig. 4B. It should be noted that when both an upper and a lower magnetic field are provided, the purpose of the lower one merely is to intensify the magnetic field.

Fig. 4C shows how individual particles behave in the magnetic field. At the top of Fig. 4C there are schematically shown magnets which are rotated in order to induce eddy currents in the electrically conductive particles, the direction of rotation being indicated by the arrow A. Below the magnets there is an air gap and under it a plastic element forming the cover of the separation space provided thereunder and further defined by the bottom. When a weakly or non-electrically conductive particle is thrown up into the magnetic field by means of the apparatus 11 producing the throwing motion (not shown in this Figure), this particle will follow the trajectory illustrated to the left in the Figure. On the other hand, an electrically conductive particle (to the right in Fig. 4C) will, according to the discussion with respect to Fig. 4A, move under acceleration in the direction of separation as a result of the rotary movement. Each single particle will be repeatedly thrown up into the magnetic field while being set in a rotary motion whose main component force cooperates with the magnetic force acting on the particle. This cooperation produces an additive effect, improving the degree of separation.

The operation of the device will now be described in more detail with reference to a practical embodiment. A mixture of electrically conductive, non-magnetic particles of two different materials, in this case copper and lead, is supplied to the device through the feeding unit 1. By means of the disc 1a, the feeding unit randomly distributes the particles into the different sections 13 of the separation means 2. The slope of the separation means 2 implicates a displacement of the particles towards the periphery thereof. As a result of the particles being thrown up into the magnetic field in a direction opposite to the direction of rotation of the magnets, along with the fact that the particles are given a positive rotary motion (see Fig. 4A) coinciding with the desired direction of separation, improved separation is achieved. By correctly selecting the frequencies/velocities for the motions of the throwing apparatus 11 and for the rotation of the hood 6 or hoods 6, 7, respectively, good separation of the constituents of the mixture is achieved, each constituent being collected separately at each side of each section, and when the particles in each section 13 during their displacement towards the periphery of the separation means pass the inner edge of the flange 14, the degree of separation is almost 100%. The final products are collected in the collecting pockets described above and passed on to the containers.

It has been found that a suitable size of the particles included in the mixture is 1-10 mm, preferably 1-8 mm. To achieve a degree of separation of about 98-99.5%, it has been found advantageous according to a preferred embodiment to rotate the hood 6, 7 at a speed of 20-50 m/sec. There is a certain relationship between the speed of rotation and the particle size. Generally, small particles require rotational speeds in the upper region of the range, whereas larger particles require rotational speeds in the lower region of the range. Optimal ratios are obtainable by simple tests.

The shape of the particles is not critical in the invention. However, it is preferred to use substantially granular particles, which means particles of a shape varying from spherical to polygonal.

According to the invention, it is convenient to separate particles which are affected differently by the magnetic field, substantially as a consequence of a difference in resistivity. Non-restricting examples of mixtures which have been successfully separated according to the invention are mixtures containing at least one of the following constituents: copper, lead, glass, plastic, cellulose etc. A condition for a successful separation according to the invention is that the mixture contains at least one electrically conductive, non-magnetic material.

Although a preferred embodiment of the invention has been described above, it is obvious to those skilled in the art that different modifications are conceivable within the scope of the invention.

## Claims

1. Method for separating at least one particulate, electrically conductive, non-magnetic material which is included as a constituent or as constituents in a mixture, the separation being performed in a space which is permeable to magnetic waves, and the mixture present in said space being subjected to an alternating magnetic field generated by a rotating means equipped with magnets, **characterised** by throwing the particles up from the bottom of said space in a direction opposite to the direction of rotation of said means generating the magnetic field, and corresponding to a throwing angle $\alpha$ relative to the horizontal plane, $0 < \alpha < 90°$, and arranging said means over said space.

2. Method as claimed in claim 1, **characterised** in that the magnetic field is generated by means arranged both above and below said space.

3. Method as claimed in claim 1 or 2, **characterised** in that said space is closed.

4. Device for separating at least one electrically conductive, non-magnetic material which is included as a constituent or as constituents in a mixture, comprising a separation space (2, 3, 4) permeable to magnetic waves, means (5) for generating an alternating magnetic field, and feeding and discharging means, **characterised** in that the means (5) is a rotating means equipped with magnets, and that a throwing apparatus (11) is provided for throwing up the particles in said space in a direction opposite to the direction of rotation of said means (5), which is disposed above said space.

5. Device as claimed in claim 4, **characterised** in that additional means for generating an alternating magnetic field is disposed below said space.

6. Device as claimed in claim 4 or 5, **characterised** in that the bottom (4) of the separation space is formed by the top face of the throwing apparatus (11).

7. Device as claimed in any one of claims 4-6, **characterised** in that the separation means (2) is divided into sections by means of webs (12) extending from its centre radially outwards towards its periphery, and that deflecting elements in the form of flanges (14) extend partially along imaginary centre radii in each section (13) for dividing each section (13) into at least two chambers (15, 16).

8. Device as claimed in claim 7, **characterised** in that the discharging means is connected to the periphery of the separation means (2) for discharging the separated material from the respective chamber (15, 16).

FIG.1

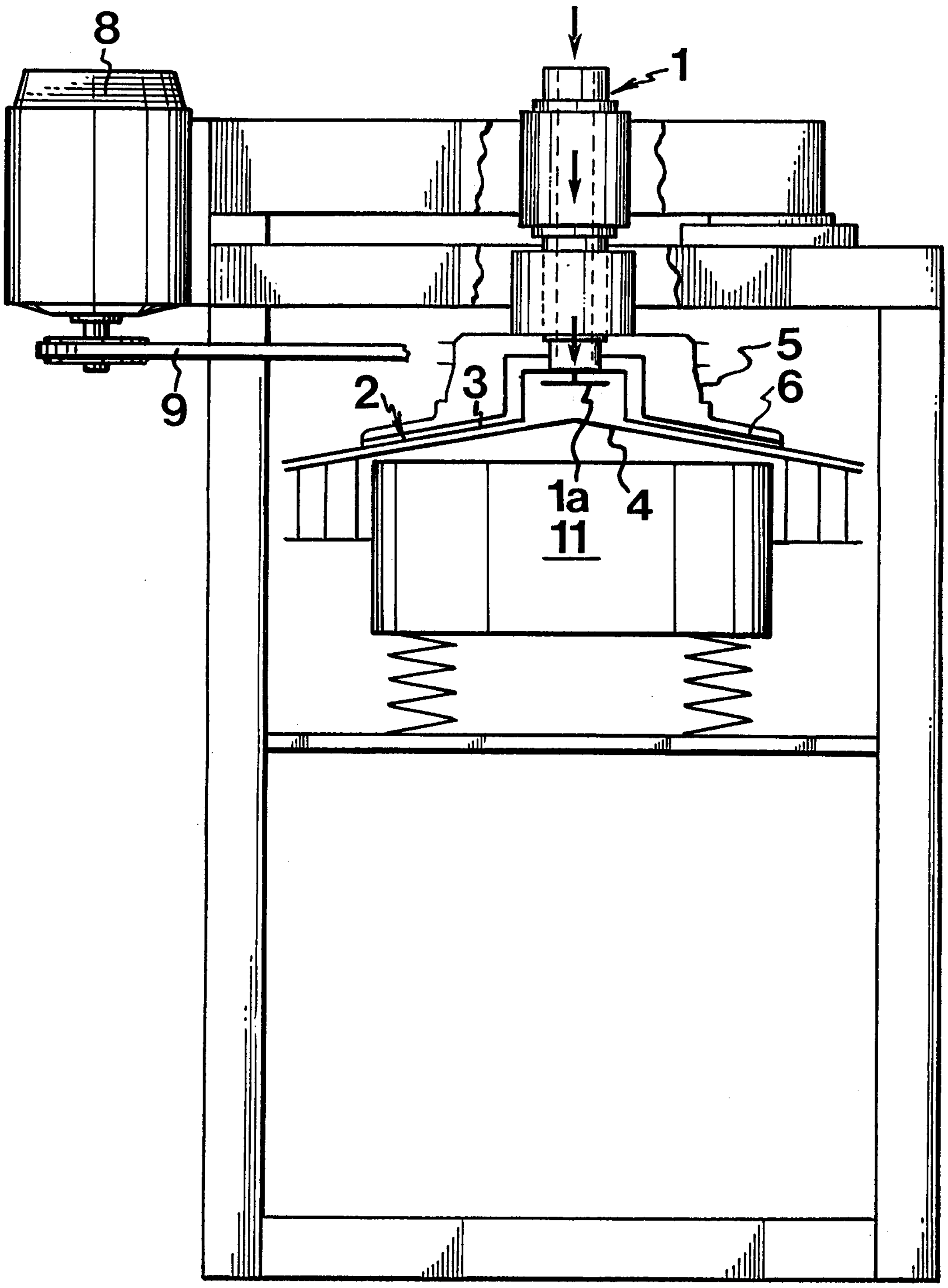


FIG. 2

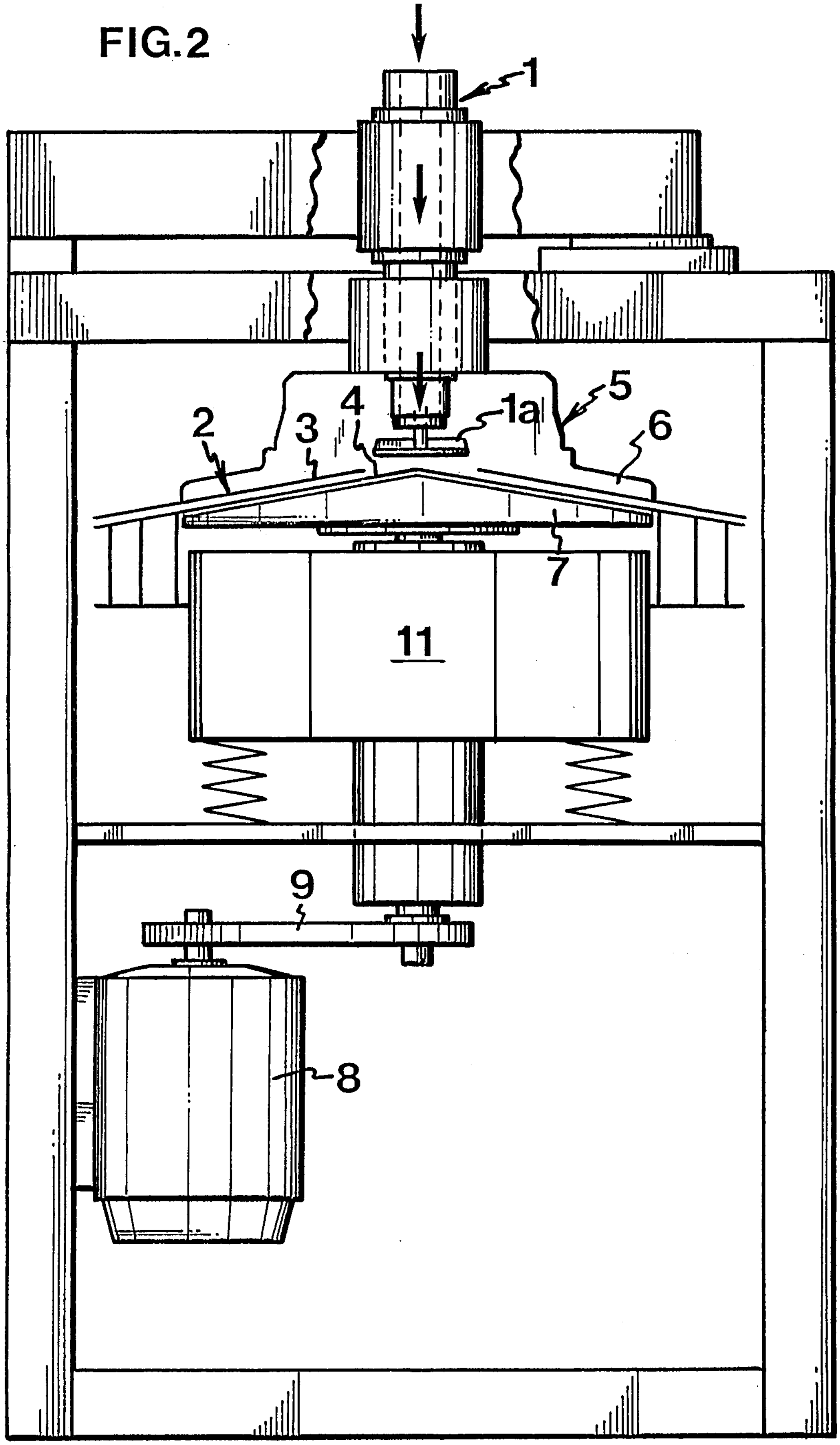
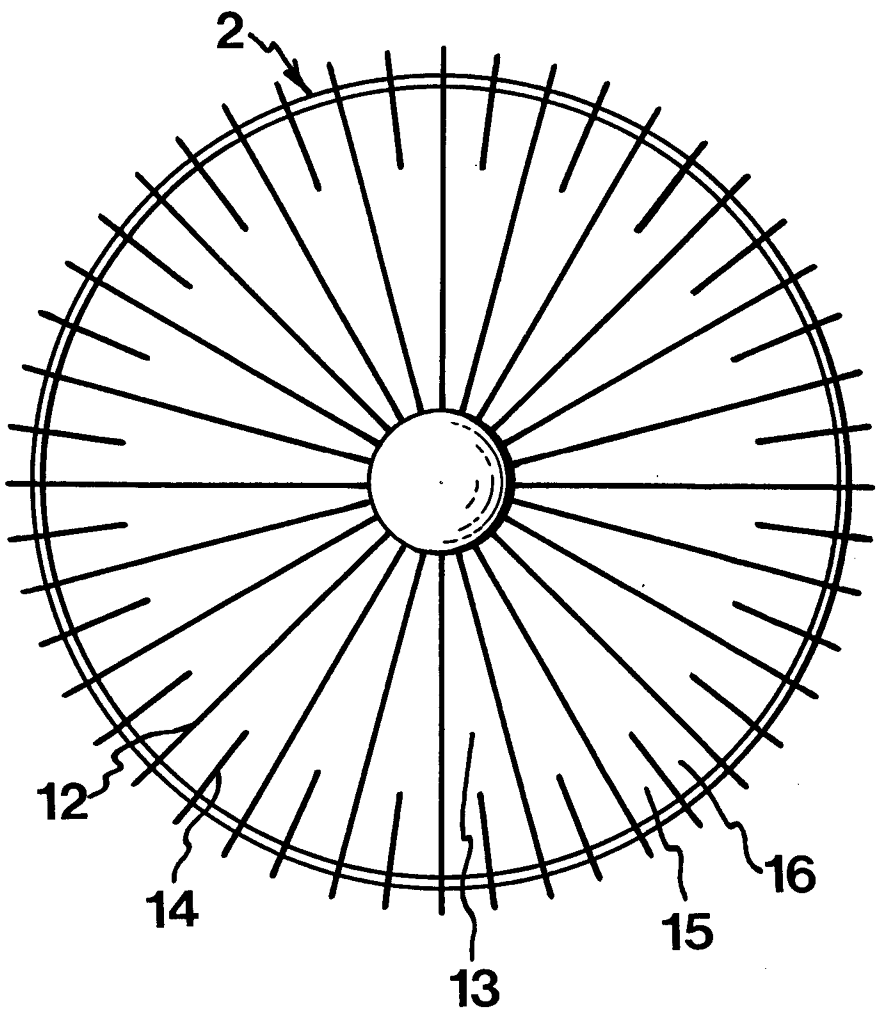
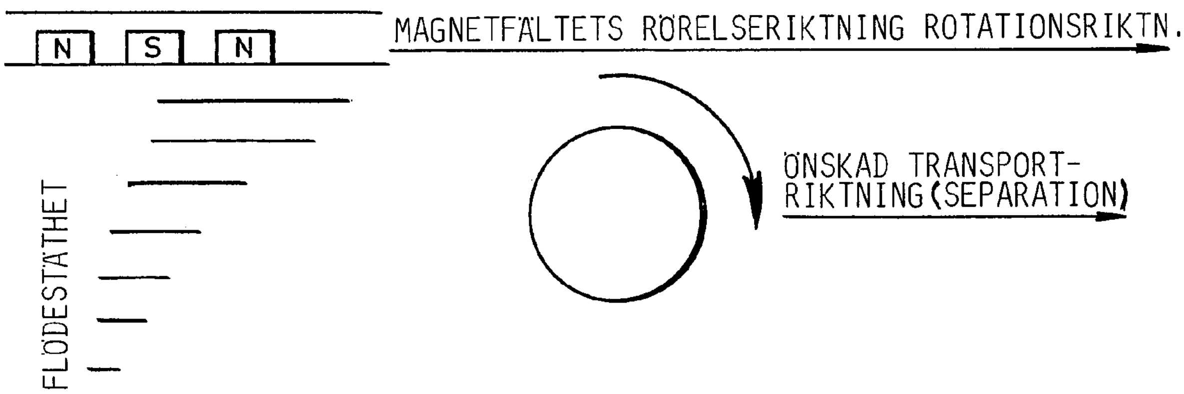


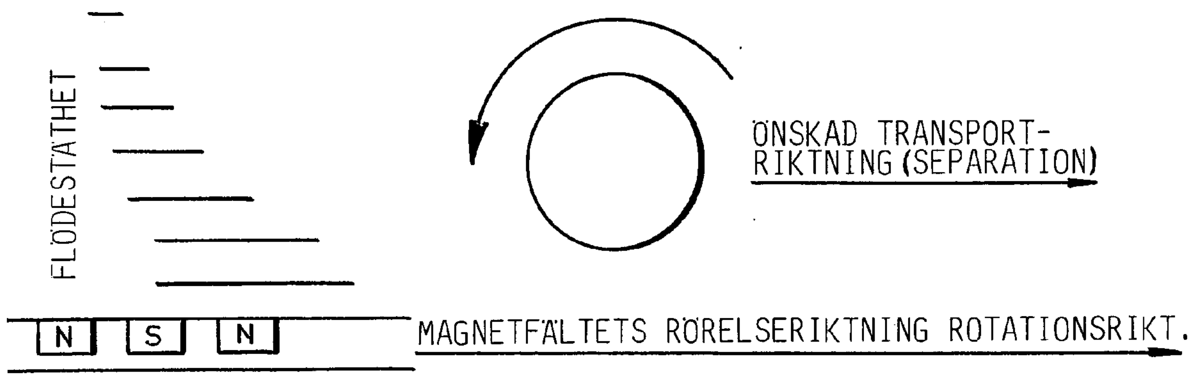
FIG.3



## FIG.4A




## FIG.4B




## FIG.4C