

## MAGNETIC SEPARATION APPARATUS

### Technical Field

5           The present invention relates to a magnetic separation apparatus which in particular is capable of separating and removing magnetic flocs from raw water by letting the magnetic flocs be adsorbed onto magnetic disks.

### Background Art

10           As a kind of a device that functions to remove pollutant substances in raw water of sewage, industry sewage, etc. there is one known as a magnetic separation apparatus. This magnetic separation apparatus adopts a method so called a magnetic seed method in which pollutant substances in raw water are turned into forms of magnetized magnetic flocs by adding flocculating agent and magnetic powder into the raw water, and by letting the magnetic flocs F be adsorbed onto magnetic disks  
15           having magnets being arranged thereto, the magnetic flocs F can be separated and removed from the raw water.

          Patent Document 1 discloses a solid-liquid separation apparatus which incorporates a magnetic separation apparatus. According to Patent Document 1, in the magnetic separation apparatus, a plurality of magnetic disks to which magnets are  
20           attached are arranged on a rotation axis at certain intervals inside a separation tank. In this structure, magnetic flocs are removed and retrieved from raw water by letting the magnetic flocs be adsorbed onto the magnetic disks.

Patent Document 1: Japanese Patent Application Laid-Open No. 10-244424

### 25   Disclosure of the Invention

#### Problems to be Solved by the Invention

          However, in the conventional magnetic separation apparatuses, the ability to remove magnetic flocs from raw water is still not sufficient in terms of the following points.

(1) In the magnetic separation apparatus, it is important that the raw water supplied to the separation tank contacts equally with each of the plurality of the magnetic disks in order to efficiently remove the magnetic flocs inside the raw water. In this respect, however, in the conventional magnetic separation apparatuses, water  
5 flow inside the separating tank can easily be biased.

(2) In a case of adopting a structure in which the magnetic disks are substantially half sunk in the raw water inside the separation tank, the magnetic flocs adsorbed onto the magnetic disks can easily come off the surfaces of the magnetic disks while they are inside the raw water, whereas the magnetic flocs can become  
10 hard to come off when they are dried and fixed to the surfaces of the magnetic disks at the time when they are carried into the air out from the raw water due to rotation of the magnetic disks. In this respect, the conventional magnetic separation apparatuses are not taking adequate measures with respect to the problem of the magnetic flocs once adsorbed onto the magnetic disks coming off while inside the  
15 raw water, and the problem as to how the magnetic flocs adsorbed onto the magnetic disks should be effectively removed once they are out in the air.

The present invention is provided in view of such circumstances, and the object of the present invention is to resolve the problems the conventional magnetic separation apparatuses have concerning adsorption separation efficiency and retrieval  
20 efficiency of magnetic flocs, and to provide a magnetic separation apparatus which is capable of removing magnetic flocs contained in raw water with high efficiency.

#### Means for Solving the Problems

For the purpose of achieving the above-mentioned object, a magnetic  
25 separation apparatus in accordance with a first aspect of the present invention, includes: a separation tank to which raw water containing magnetic flocs is to flow into, the separation tank having a feed-water inlet provided in the lower end of the separation tank for supplying the raw water to the separation tank as an upward flow; a plurality of magnetic disks which adsorb the magnetic flocs by use of magnetic  
30 force, the plurality of magnetic disks being arranged at predetermined intervals on a rotation axis provided in the separation tank and being substantially half sunk in the raw water in the separation tank; a retrieving device which retrieves the magnetic

flocs adsorbed onto the magnetic disks; flow dividing members, provided directly underneath the respective magnetic disks, which divide the flow of the raw water supplied from the feed-water inlet in right and left directions with respect to surfaces of the magnetic disks and in a thickness direction of the magnetic disks; and a pair of  
5 troughs, provided on opposing sides of the separation tank parallel to the rotation axis, where treated water after removing the magnetic flocs from the raw water by the magnetic disks overflows.

Therefore, according to the first aspect, raw water supplied from a feed-water inlet provided in a lower end of a separation tank hits flow dividing members  
10 and is divided its flow in the radial right and left directions of magnetic disks and in the thickness direction of the magnetic disks. In this way, by letting the raw water supplied from the feed-water inlet hit the flow dividing members and being divided its flow in the right and left directions of the magnetic disks and in the thickness direction of the magnetic disks, a flow rate of the raw water flowing among the  
15 magnetic disks is reduced, whereby the raw water becomes a slow upward flow that moves upwardly passing among the magnetic disks. Thereby, it becomes possible to have the magnetic flocs in the raw water efficiently adsorbed onto the magnetic disks.

Moreover, by providing a pair of troughs on opposing sides of the separation tank parallel to a rotation axis, where treated water after removing magnetic flocs  
20 from raw water by the magnetic disks overflows, divided flows are not retained inside the separation tank, and thus, it becomes possible to promptly discharge the treated water out from the separation tank.

In addition, by arranging flow dividing members directly underneath the respective magnetic disks, it is possible to prevent the raw water from becoming a  
25 fast upward flow when flowing through the vicinity of the surfaces of the magnetic disks. Therefore, the magnetic flocs once adsorbed onto the magnetic disks will not come off and fall inside the raw water.

In accordance with a second aspect of the present invention, in the magnetic separation apparatus according to the first aspect, the flow dividing member is formed  
30 so that the flow dividing member has a thickness at the upper end being the same as a thickness of the magnetic disk, and has a wedge shape at cross section in which the thickness becomes thinner towards the lower end.

By forming flow dividing members in such shapes according to the second aspect, it is possible to have the flow of the raw water supplied through the feed-water inlet divided in the radial right and left directions of the magnetic disks and in the thickness direction of the magnetic disks with good accuracy.

5 In accordance with a third aspect of the present invention, in the magnetic separation apparatus according to one of the first and second aspects, the feed-water inlet is formed in a square tube shape which is longer in the direction of the rotation axis.

10 By having a water inlet formed in a square tube shape according to the third aspect, water can be easily supplied equally inside the separation tank, whereby the removing efficiency of the magnetic flocs can be further improved.

In accordance with a fourth aspect of the present invention, the magnetic separation apparatus according to one of the first to third aspects, further includes sealing plates provided between peripheral surfaces of the respective magnetic disks and an inner surface of the separation tank in a way such that base ends of the sealing plates are fixed to the inner surface of the separation tank and apical ends of the sealing plates as being free ends contact the peripheral surfaces of the magnetic disks.

15 By providing sealing plates between peripheral surfaces of the respective magnetic disks and the inner surface of the separation tank, according to the fourth aspect, it is possible to block a flow that takes a shorter route through the peripheral surfaces of the magnetic disks and overflows into the troughs without contacting the surfaces of the magnetic disks. Thereby, it is possible to further improve the removing efficiency of the magnetic flocs.

25 In accordance with a fifth aspect of the present invention, in the magnetic separation apparatus according to one of the first to fourth aspects, the retrieving device includes: gutter-shaped scrapers, each of which being provided, in a form of a gutter extending from the vicinity of the rotation axis to the outside of the separation tank, between two adjacent rotating magnetic disks just before entering the raw water from the air, each of the gutter-shaped scrapers having edge parts in the upper ends of both sides contact the surfaces of the magnetic disks with predetermined urging force to scrape off the magnetic flocs adsorbed onto the surfaces of the magnetic disks; and conveying devices provided inside respective gutter-shaped scrapers, each of which

conveys the magnetic flocs being scraped off, dropped and accumulated inside the gutter-shaped scraper to the outside of the separation tank.

According to the fifth aspect, gutter-shaped scrapers are provided, each of which is in a form of a gutter extending from the vicinity of the rotation axis to the outside of the separation tank, between two adjacent rotating magnetic disks just before entering the raw water from the air, and which has edge parts in the upper ends of both sides contact the surfaces of the magnetic disks with predetermined urging force to scrape off the magnetic flocs adsorbed onto the surfaces of the magnetic disks. Thereby, it is possible to unfailingly scrape off the magnetic flocs even when the magnetic flocs are the ones that are being fixed to the surfaces of the magnetic disks due to being dried in the air, and it is possible to unfailingly retrieve the magnetic flocs being scraped off into the gutter-shaped scrapers.

#### Advantage of the Invention

As described above, the magnetic separation apparatus according to any of the aspects of the present invention is capable of resolving the problems concerning adsorption separation efficiency and retrieval efficiency of the magnetic flocs, which are problems conventional magnetic separation apparatuses have, and removing the magnetic flocs contained in the raw water with high efficiency.

#### Brief Description of the Drawings

Fig. 1 is a block diagram illustrating a flow of operation in a polluted water clarification system which incorporates a magnetic separation apparatus according to the present invention;

Fig. 2 is a schematic view of devices that construct the polluted water clarification system;

Fig. 3 is a perspective view illustrating a cross section of a part of the magnetic separation apparatus according to the present invention;

Fig. 4 is a sectional side view of the magnetic separation apparatus according to the present invention;

Fig. 5 is a sectional front view of the magnetic separation apparatus according to the present invention;

Fig. 6 is an explanatory diagram illustrating operation of a flow dividing member arranged in the magnetic separation apparatus according to the present invention;

Fig. 7 is a perspective view illustrating sealing plates arranged in the magnetic separation apparatus according to the present invention;

Fig. 8 is explanatory diagram illustrating differences between outmost magnetic disks according to the conventional art and the present invention;

Fig. 9 is an explanatory diagram illustrating a relation between a magnetic disk and a gutter-shaped scraper in the magnetic separation apparatus according to the present invention;

Fig. 10 is an explanatory diagram illustrating a retrieving device adopting a screw conveyer system;

Fig. 11 is an explanatory diagram illustrating a relation between a screw conveyer and a gutter-shaped scraper;

Fig. 12 is an explanatory diagram illustrating a retrieving device adopting a finned belt conveyer system; and

Fig. 13 is an explanatory diagram illustrating a relation between a fin in the finned belt conveyer system and a gutter-shaped scraper.

#### Description of Symbols

- 10...contaminated-water purifying system
- 12...raw water pump
- 14...flocculation device
- 14A...rapidly-stirring tank
- 14B...slowly-stirring tank
- 16...magnetic-powder adding device
- 18...coagulant adding device
- 19...stirring blade
- 20...magnetic separation apparatus
- 24...filter separation device
- 25...dehydrator
- 26...rotating drum filter

- 28...showering device
- 29...circulation pump
- 30...pump
- 31...sleeve
- 5 32...separation tank
- 33...disk plate
- 34...rotating shaft
- 35...bearing
- 36...magnetic disk
- 10 37...permanent magnet
- 38...collecting device
- 39...motor
- 40...trough
- 41...side walls
- 15 42...floc collecting tank
- 43...rectangular column pipe
- 44...inlet
- 45...case
- 46...diverging member
- 20 48...sealing plate
- 50...rotatable shaft
- 52...reinforcement member
- 55...lid member
- 60...gutter-shaped scraper
- 25 62...conveying device
- 64...screw conveyer
- 66...belt conveyer with fins
- 68...pulley
- 69...fins
- 30 70...endless belt
- F...magnetic floc

### Best Mode for Carrying Out the Invention

In the following, a preferred embodiment of a magnetic separation apparatus according to the present invention will be described with reference to the drawings.

Fig. 1 is a block diagram illustrating a flow of operation in a polluted water clarification system 10 which incorporates a magnetic separation apparatus 20 according to the present invention. Fig. 2 is a schematic diagram of a flocculation device 14, the magnetic separation apparatus 20 and a filter separation device 24.

As shown in Fig. 1, in the polluted water clarification system 10, first, raw water is conveyed to a rapid stirring tank 14A in the flocculation device 14 by a raw water pump 12. In certain places along a pipe arrangement connecting the raw water pump 12 and the rapid stirring tank 14A, a magnetic powder adding device 16 for adding magnetic powder, and a flocculating agent adding device 18 for adding a flocculating agent are provided so as to add the magnetic powder and the flocculating agent to the raw water flowing inside the pipe arrangement. As for the magnetic powder, ferrosioferric oxide can be used preferably. As for the flocculating agent, a soluble inorganic flocculating agent such as polyaluminum chloride, ferric chloride, ferric sulfate, etc. can be used preferably. Meanwhile, although it is not shown in the diagram, it is preferable that a strainer is provided in the system such that the raw water can be filtered by having comparatively large size dirt of several millimeter size removed before having the magnetic powder and the flocculating agent added.

In the rapid stirring tank 14A, by rapidly stirring the raw water, the added magnetic powder and the flocculating agent using stirring fins 19 which rotate in high speed, tiny magnetic flocs F (also known as magnetic micro-flocs) each of which with a size of around several tens of micrometers ( $\mu\text{m}$ ) are to be formed. It is preferable that a rotating speed at the edges of the stirring fins 19 is about 1 to 2 m/second (meter per second). The magnetic powder, and solid floating particles, bacteria, plankton, etc. in the raw water are to be taken up by the magnetic micro-flocs.

Next, the raw water containing the magnetic micro-flocs is conveyed to a slow-speed stirring tank 14B in the flocculation device 14. In the vicinity of a communicating room 14C that connects the rapid stirring tank 14A and the slow-speed stirring tank 14B, a high polymer flocculating agent adding device 21 is provided so as to add a high polymer flocculating agent to the raw water flowing

through the communicating room 14C. Here, as for the high polymer flocculating agent, one of an anionic system and a nonionic system can be used preferably.

In the slow-speed stirring tank 14B, by slowly stirring the magnetic micro-flocs and the high polymer flocculating agent using stirring fins 19 which rotate in low speed, large size magnetic flocs F each of which with a size of around several hundreds micrometers ( $\mu\text{m}$ ) to several millimeters (mm) are formed. As shown in Fig. 2, it is preferable that the slow-speed stirring tank 14B is configured as a multistage stirring tank including continuous multiple stages with stirring tanks (A, B and C). In this case, a rotating speed of the stirring fins 19 should decrease as it goes further down the stream from the slow-speed stirring tank A in the upstream side to the slow-speed stirring tank C in the downstream side. Thereby, the magnetic flocs F can grow bigger as they go further down the stream from the slow-speed stirring tank A in the upstream side to the slow-speed stirring tank C in the downstream side, by which it becomes possible to prevent the grown magnetic flocs from breaking up. As for a rotating speed at the edges of the stirring fins 19, it is preferable, for instance, that the rotating speed is about 0.5 to 1 m/second in the slow-speed stirring tank A, about 0.3 to 0.7 m/second in the slow-speed stirring tank B, and about 0.1 to 0.3 m/second in the slow-speed stirring tank C.

As shown in Fig. 2, it is preferable that the flocculation device 14 has an integral structure that includes the rapid stirring tank 14A, the communicating room 14C and the slow-speed stirring tank 14B. However, it is also possible to have a structure in which these components are connected by a pipe arrangement.

The raw water containing the magnetic flocs F of which sizes have grown bigger, are to be conveyed to the magnetic separation apparatus 20 according to the present invention. The magnetic separation apparatus 20 is intended to adsorb and separate the magnetic flocs F from the raw water using magnetic force. By the magnetic separation apparatus 20, about 90% of the magnetic flocs F in the raw water are separated and removed. As for a structure of the magnetic separation apparatus 20, details will be described after the entire operation flow of the polluted water clarification system 10 is explained.

The magnetic flocs F having been removed from the raw water by the magnetic separation apparatus 20 are to be dehydrated by a dehydration device 25,

which could be a centrifuge machine, a belt press machine or the like, so that their moisture content will be reduced down to about 80%. After that, the magnetic flocs F are to be loaded on a truck, etc. to be carried to a landfill site, an incineration plant, a compost manufacturing factory, etc.

5           On the other hand, the treated water having gone through the processes in the magnetic separation apparatus 20 is next conveyed to the filter separation device 24. In the filter separation device 24, the treated water is to go into a rotating drum filter 26 where the treated water is filtered from the inside to the outside of the rotating drum filter 26 to remove the magnetic flocs F still remaining in the treated water.

10           In this way, it is possible to purify the raw water containing pollutant substances such as dusts, solid floating particles, bacteria, plankton, etc. The magnetic flocs F attached to the rotating drum filter 26 are accumulated in a hopper arranged inside the rotating drum filter 26 by being showered with cleaning water outputted from a showering device 28 arranged on the upper side of the rotating drum  
15           filter 26. Then the accumulated magnetic flocs F are discharged outside the device. In this case, it is preferable that some of the treated water being purified by the rotating drum filter 26 is returned to the showering device 28 by a circulation pump 29 so that the treated water can be reused as cleaning water. Discharged cleaning water which has turned dirty by containing magnetic flocs F due to the showering is  
20           brought back to a previous stage of the raw water pump by a pump 30.

[Magnetic Separation apparatus]

Fig. 3 is a perspective view illustrating a cross section of a part of the magnetic separation apparatus 20 according to the present invention. Fig. 4 is a sectional side view of the magnetic separation apparatus 20, and Fig. 5 is a sectional  
25           front view of the magnetic separation apparatus 20.

As shown in Figs. 3 and 4, the magnetic separating device 20 according to the present invention mainly includes: a separation tank 32 where raw water containing magnetic flocs F flow into; a plurality of magnetic disks 36 which are arranged, at predetermined intervals, on a rotation axis 34 provided inside the  
30           separation tank 32 in the horizontal direction, and which adsorb the magnetic flocs F by their magnetic force; and a retrieving device 38 which retrieves the magnetic flocs F adsorbed onto the magnetic disks 36. In this embodiment, although explanation is

given on a case where three to four magnetic disks 36 are used, the number of the magnetic disks 36 is not limited to such particular numbers.

The separation tank 32 is formed in a shape of a half cylinder which is opened in the upper part and closed by side walls 41 in its both end faces (ref. Fig. 5).  
 5 On both sides (the right and the left sides in Fig. 3) of the separation tank 32, a pair of troughs 40 is formed in parallel with the rotation axis 34, and they have concave shapes at cross section. Those troughs 40 are formed integrally with the separation tank 32. In the outside of the trough 40, a floc retrieving tank 42 is provided. The floc retrieving tank 42 is formed in parallel with the trough 40, and has a concave  
 10 shape at cross section. As shown in Fig. 3, the floc retrieving tank 42 is provided on the right side (the right side in Fig. 3) where the rotating magnetic disks 36 enter in the raw water.

As shown in Fig. 5, in the upper parts of the pair of side walls 41 of the separation tank 32, the rotation axis 34 is supported by axis bearings 35 in a rotatable  
 15 way, while one end of the rotation axis 34 is connected with a motor 39. On the rotation axis 34, a plurality of magnetic disks 36 each of which having a fitting hole in the central part are fit-supported while having a predetermined interval between each other. Between each adjacent magnetic disks 36, a sleeve 31 is provided in  
 20 such a way as to adjust the interval between the adjacent magnetic disks 36 and fix the inner periphery of the adjacent magnetic disks 36. It is preferable that the interval between each adjacent magnetic disks 36 is set to a value within a range of one to three times the thickness of the magnetic disk 36. If the interval is less than one time the thickness of the magnetic disk 36, it becomes difficult for the raw water  
 25 to flow between the magnetic disks 36. Whereas if the interval is over three times the thickness of the magnetic disk 36 and becomes too wide, it becomes difficult for the magnetic disks 36 to generate strong magnetic force between each other.

It is preferable that each of the plurality of the magnetic disks 36 being supported by the rotation axis 34 sinks under the raw water in the separation tank 32 by 1/2 to 2/3 portion of it. In such case where the magnetic disks 36 are arranged  
 30 such that they partly sink under the water, the magnetic flocs F adsorbed onto the magnetic disks 36 in the raw water are retrieved by the retrieving device 38 when the magnetic disks 36 rotate and bring the magnetic flocs F to the air. Accordingly, it is

important to set such sinking rate of the magnetic disks 36 that could render adsorption and retrieval efficiencies of the magnetic flocs F the best. Therefore, for instance, making the pair of axis bearings 35 be supported by a pair of elevating machines, which are not shown, so that the magnetic disks 36 can move up and down  
 5 by a hydraulic mechanism or the like and so that the sinking rate can be made variable, should be a likeable method.

Moreover, in the lower end of the separation tank 32, a feed-water inlet 44 having a square tube shape which is longer in the direction of the rotation axis 34 is formed. This feed-water inlet 44 and an outlet of the flocculation device 14 are  
 10 connected by a pipe arrangement 43 (ref. Fig. 4). In the feed-water inlet 44, a plurality of flow dividing members 46 are arranged (ref. Fig. 5). As shown in Fig. 5, these flow dividing members 46 are arranged directly underneath the respective magnetic disks 36, and each of them has a wedge shape, at cross section, whose thickness W1 in the upper end is the same as a thickness W2 of the magnetic disk 36  
 15 and becomes thinner towards the lower end. Furthermore, as can be seen in Fig. 4, a width dimension D1 of each flow dividing member 46 is smaller than a width D2 of the feed-water inlet 44, whereby the raw water supplied through the feed-water inlet 44 can be divided into right and left gaps 44A and 44B each of which formed between the feed-water inlet 44 and the flow dividing member 46.

20 As shown in Fig. 4, by having these flow dividing members 46, the raw water supplied from the feed-water inlet 44 hits each flow dividing member 46 and its flow is divided in radial right and left directions of each magnetic disk 36. In this way, by having the raw water supplied through the feed-water inlet 44 divided into two flows in the right and left directions by letting the raw water hit each flow  
 25 dividing member 46, a flow rate of the raw water flowing between each adjacent magnetic disks 36 can be reduced, whereby the raw water becomes a slow upward flow that moves upwardly passing among the magnetic disks 36. Thereby, it is possible to have the magnetic flocs F in the raw water efficiently adsorbed onto the magnetic disks 36. In addition, by reducing the flow rate of the upward flow, the  
 30 magnetic flocs F once adsorbed onto the magnetic disks 36 becomes hard to come off.

Furthermore, as shown in Fig. 5, the raw water entering the separation tank 32 from the feed-water inlet 44 is also divided in a thickness direction of the

magnetic disks 36 by the flow dividing members 46. Thereby, it is possible to prevent the magnetic flocs F adsorbed onto the magnetic disks 36 from coming off due to the flow of the raw water being supplied through the feed-water inlet 44. That is, as can be understood from Fig. 5, without the arrangement of the wedge-shaped flow dividing members 46, the peripheral surfaces 36a of the magnetic disks 36 are exposed directly to the upward flow of the raw water being supplied from the feed-water inlet 44.

That is, as can be seen in Fig. 6, the flow of the raw water in a state where there are no flow dividing members 46 become a fast upward flow as shown by the dotted lines that flows through the vicinity of the surfaces of the magnetic disks 36, and therefore, among the magnetic flocs F that have adsorbed onto the surfaces of the magnetic disks 36, especially the ones near the peripheral surfaces 36a might get scraped off due to the flow of the raw water and thus might drop into the raw water. On the other hand, by having the peripheral surfaces 36a of the magnetic disks 36 not exposed directly to the flow of the raw water due to the flow dividing members 46, the raw water entering through the feed-water inlet 44 will flow with a slower speed as it hits the flow dividing members 46 and it is further divided in the thickness direction of the magnetic disks 36, as shown by the solid arrowed lines in Fig. 6. Therefore, the magnetic flocs F once adsorbed onto the surfaces of the magnetic disks 36 are not scraped off due to the flow of the raw water.

In addition, as shown in Fig. 4, the separation tank 32 is provided with sealing plates 48 which seal the gaps between the peripheral surfaces 36a of the magnetic disks 36 and the inner surface of the separation tank 32 so that the raw water supplied from the feed-water inlet 44 does not take a shorter route through the peripheral surfaces 36a of the magnetic disks 36 and flow out into the troughs 40.

As shown in Fig. 7, the sealing plates 48 have their base ends fixed to a turning axis 50 which is supported by the separation tank 32 in a turnable way, and have their apical ends as being free ends touching the peripheral surfaces 36a of the magnetic disks 36. The turning axis 50 is urged by a spring, etc., which is not shown, to rotate in the direction of the arrow. Thereby, since the sealing plates 48 are contacting the peripheral surfaces 36a of the magnetic disks 36 with predetermined contact force, they can prevent the raw water from taking a shorter

route through the peripheral surfaces 36a of the magnetic disks 36 without disturbing the rotation of the magnetic disks 36. As for the material of the sealing plates 48, elastic material which is softer than the magnetic disk 36 should be used preferably, and in this respect, rubber plates, for instance, can be suitable for use as the sealing plates.

Now a description will be given on the magnetic disks 36.

The magnetic disk 36 is configured so that, in a nonmagnetic case 45 having a torus-shape cavity inside, a ferromagnetic disk substrate 33 is sandwiched between permanent magnet pieces 37. In the central part of the disk substrate 33, there is a hole for reeving a rotation axis 34. Normally, three or more magnetic disks 36 are mounted on the rotation axis 34.

With respect to such magnetic disks 36, in the conventional art as shown in Fig. 8(A), the outmost magnetic disks 36A arranged on both ends of the rotation axis 34 and the inner magnetic disks 36B arranged inwardly near the center from both ends of the rotation axis 34 have the permanent magnet pieces 37 on both sides of their ferromagnetic disk substrates 33. Therefore, in the conventional cases, there are problem including magnetic leakage from the outmost magnetic disks 36A to the outside of the separation tank 32, and deformation of the outmost magnetic disks 36A.

With respect to the inner magnetic disks 36B, because there are opposed magnetic disks on both sides of each of them, as long as they are arranged at equal intervals, the magnetic force of the inner magnetic disks 36B should be kept in a balanced state and thus the inner magnetic disks 36B are free of the problems of magnetic leakage, deformation, etc.

As a counter measure to such problems in the conventional art, Fig. 8(B) shows a different arrangement of the magnetic disks 36A and 36B. As shown in Fig. 8(B), the inner magnetic disks 36B have the same structure as the ones in the conventional art, that is, each of them is structured as having permanent magnet pieces 37 arranged on both sides of the disk substrate 33 in such a way that the ferromagnetic disk substrate 33 is sandwiched therebetween. On the other hand, with respect to the outmost magnetic disks 36A, each of them has the permanent magnet pieces 37 for exerting magnetic force arranged only on the inner side surface of the disk substrate 33 (i.e. the surface on the side of the inner magnetic disk 36B)

while a single iron plate 52 is arranged on the outer side surface of the disk substrate 33 in such a way that the magnet pieces 37 and iron plate 52 are sandwiching the disk substrate 33 therebetween. In this case, the disk substrate 33 is essentially ferromagnetic, although the iron plate 52 can be either ferromagnetic or nonmagnetic.

5 In addition, the disk substrate 33 and the iron plate 52 can have an integrated form by being structured as a one thick ferromagnetic body. Thereby, the outmost magnetic disks 36A are arranged to be able to have more enhanced stiffness than the inner magnetic disks 36B. In enhancing the stiffness of the outmost magnetic disks 36A, it is important that the stiffness be enhanced to the extent that the outmost magnetic  
10 disks 36A is not deformed due to the influence of the magnetic force from the inner magnetic disks 36B. Accordingly, it is preferable that a thickness of the iron plate 52 is properly determined on the basis of a distance between the outmost magnetic disk 36A and the inner magnetic disk 36B, magnetic force of the permanent magnet pieces 37, material of the disk substrate 33, and so forth.

15 With respect to the outmost magnetic disk 36A or with respect to the inner magnetic disk 36B, in the case of having the disk substrate 33 made of ferromagnetic material, it should be more preferable that the permanent magnet pieces 37 are glued to the disk substrate 33 with an adhesive agent, although it is also possible to have the permanent magnet pieces 37 directly attached to the disk substrate 33 using the  
20 magnetic force of the permanent magnet pieces 37. At this time, it is also possible to arrange such that resin is molded to the space formed inside the case 45.

Furthermore, in order to enhance the stiffness of the magnetic disks 36, it is also possible to have pockets (not shown) formed on the surfaces of the ferromagnetic disk substrates 33 so that the permanent magnet pieces 37 can fit in those pockets.

25 A method for manufacturing the magnetic disk 36 having a plurality of permanent magnet pieces 37 fixed to the surfaces of the disk substrate 33 includes: a disk substrate formation process for forming the disk substrate 33 into a honeycomb structure in which at least one of the surfaces of the disk substrate 33 have a plurality of holes serving as the above-mentioned pockets; a magnet fitting process for fitting  
30 the permanent magnet pieces 37 in the pockets formed on the disk substrate 33; and a placing process for placing the disk substrate 33 with the permanent magnet pieces 37 being fitted therein inside the case 45 having a torus-shape cavity formed inside.

Thereby, it is possible to enhance the stiffness of the magnetic disk 36 since the sidewalls of the pockets serve as ribs (reinforcing members). In this case, it is necessary that the pockets are made of nonmagnetic material, and the pockets are to be glued to the ferromagnetic disk substrate 33 with an adhesive agent. The reason  
 5 for this is that, if the pockets are made of magnetic material, ferromagnetic material in particular, magnetic flux will be absorbed by the sidewalls of the pockets, which results in increasing magnetic field only in the vicinity of the surfaces of the magnets while it will become difficult to form high magnetic field in places apart from the permanent magnet pieces 37 with respect to the magnetization direction.

10 By structuring the outmost magnetic disks 36A in this way, it is possible to resolve the problem of magnetic leakage with a simple measure without having to adopt a magnetic shield, a magnetic coil, etc., and what is more, the outmost magnetic disks 36A will not be deformed. Meanwhile, in forming the inner magnetic disk 36B as having pockets, the pockets should be formed on both sides of the disk  
 15 substrate 33.

However, since the permanent magnet pieces 37 are not arranged on the outer surfaces of the disk substrates 33 of the respective outmost magnetic disks 36A, there is a risk that the raw water passing between the outer surfaces of the respective outmost magnetic disks 36A and the inner surface of the separation tank 32 may flow  
 20 out into the troughs without having the magnetic flocs F being adsorbed and separated. As a countermeasure to this problem, as shown in Fig. 5, shielding members 54 are arranged to fill in the gaps between the outer surfaces of the respective outmost magnetic disks 36A and the inner surface of the separation tank 32. These shielding members 54 are arranged in such a way as to not disturb the rotation  
 25 of the outmost magnetic disks 36A. As to the shielding members 54, it is important that they do not disturb the rotation of the outmost magnetic disks 36A, and thus, material that has less friction and that is soft such as resin, sponge, etc. can be used preferably. In this way, even though the permanent magnet pieces 37 are not  
 30 arranged on the outer surfaces of the disk substrates 33 of the respective outmost magnetic disks 36A, the magnetic flocs F are not flow out into the troughs 40 as they are. As can be seen in Fig. 5, there are still concave shaped gaps formed between the outer surfaces of the respective outmost magnetic disks 36A and the inner surface

of the separation tank 32 even though there are shielding members 54 to seal the gaps. However, the raw water is not retained in those concave shaped gaps due to the influence of the centrifugal force caused by the rotation of the outmost magnetic disks 36A.

5           In addition, there is a method that forms the cases 45 of the respective magnetic disks 36 into honey comb structures for the purpose of enhancing the stiffness of the outmost magnetic disks 36A. By adopting this method, it is also possible to have lighter magnetic disks 36. This method regarding the honey comb structure is not necessary applicable to the outmost magnetic disks 36A only, but can  
10 be applied to the inner magnetic disks 36B as well.

Now a description will be given on the floc retrieving device 38 that retrieves the magnetic flocs F adsorbed onto the magnetic disks 36.

The floc retrieving device 38 includes mainly composed of gutter-shaped scrapers 60 and conveying devices 62.

15           Each of the gutter-shaped scrapers 60 is provided in a form of a gutter that extend from the vicinity of the rotation axis 34 to the upper side of the floc retrieving tank 42, and it is arranged such that it comes between two adjacent rotating magnetic disks 36 just before entering the raw water from the air (ref. Fig. 5). Each gutter-shaped scraper 60 is configured in a manner that its edge parts 60A in the upper ends  
20 of both sides of it contact with the surfaces of the magnetic disks 36 with predetermined urging force, by which the magnetic flocs F adsorbed onto the surfaces of the magnetic disks 36 can be scraped off.

The conveying devices 62 are provided inside respective gutter-shaped scrapers 60, and each of them is to convey the magnetic flocs F, which have been  
25 scraped off, dropped and piled up inside the gutter-shaped scraper 60, to the upper side of the floc retrieving tank 42 where it drops the magnetic flocs F into the floc retrieving tank 42. As for the conveying device 62, a screw conveyer 64 or a finned belt conveyer 66 can be used preferably. Figs. 9 to 11 are showing the case when the screw conveyer 64 is adopted, whereas Figs. 12 and 13 are showing the case when  
30 the finned belt conveyer 66 is adopted. In Figs. 9, 10 and 12, only the magnetic flocs F that are on the parts of the magnetic disks 36 exposed in the air are shown.

As shown in Fig. 9, the gutter-shaped scraper 60 has its edge parts 60A in the upper ends of both sides of it contact the surfaces of the magnetic disks 36 with predetermined pressing force, while the upper end edge parts 60A are formed in sharp thin-walled shapes. With this structure, the magnetic flocs F adsorbed onto the surfaces of the magnetic disks 36, which are rotating in the clockwise direction, are to be scraped off by the upper end edge parts 60A of the gutter-shaped scraper 60, and dropped into the gutter-shaped scraper 60.

As shown in Figs. 9 to 11, a screw part 64A of the screw conveyer 64 is contained inside the gutter-shaped scraper 60, and one end of the screw part 64A is connected to a motor 64B. In this case, as shown in Fig. 11, the inner surface of the gutter-shaped scraper 60 from its sides to bottom should preferably have a semicircular shape so that no dead space is formed in conveyance. Thereby, the magnetic flocs F which have been dropped and piled up inside the gutter-shaped scraper 60 is conveyed by the screw conveyer 64 to the upper side of the floc retrieving tank 42 where they are to be dropped inside the floc retrieving tank 42.

On the other hand, in the case of adopting the finned belt conveyer 66 to function as the conveying device 62, the structure is as shown in Figs. 12 and 13. The finned belt conveyer 66 is provided with a pair of pulleys 68 on both sides of the magnetic disk 36 in the radial direction of the magnetic disk, and an endless belt 70 having fins 69 is wrapped around the pair of pulleys. One of the pulleys 68 in the pair is connected to a driving device such as a motor, etc., which is not shown. This endless belt 70 is not supposed to contact with the surfaces of the magnetic disks 36. The fins 69 are provided in a large number at predetermined intervals on the outer surface of the endless belt 70, and they are formed as being vertical with respect to the endless belt 70. In this case, as shown in Fig. 13, the inner surface of the gutter-shaped scraper 60 from its sides to bottom should preferably have a shape that suites the shape of the fin 69 so that no dead space will be formed for conveyance. For instance, if the shape of the fin 69 is an inverted trapezoid, then the inner surface shape of the gutter-shaped scraper 60 should also be an inverted trapezoid.

In Figs. 9 to 13, although supporting mechanisms for the gutter-shaped scraper 60 and the pulleys 68 of the finned belt conveyer 66 are not shown in particular, it is possible to have them supported by the main frame of the magnetic

separation apparatus 20, for instance. As for the slope of the gutter-shaped scraper 60, the one shown in Fig. 10 (i.e. the one with the screw conveyer) has a slope which is diagonally right up, whereas the one shown in Fig. 12 (i.e. the one with the finned belt conveyer) has a slope which is diagonally right down. However, it is preferable that the slope is diagonally right up. By having a diagonally right up slope for the gutter-shaped scraper 60, it is possible to prevent moisture coming out of the magnetic flocs F, while the magnetic flocs F drop and pile up inside the gutter-shaped scraper 60 and then be conveyed by the conveying device, from flowing into the floc retrieving tank 42. It is important that the magnetic flocs F to be retrieved by the floc retrieving tank 42 should contain moisture as low as possible to have reduced volume. For this purpose, it is preferable that an adjustment device (not shown) for adjusting a slope of the retrieving device 38 as a whole is provided so that the diagonally right up slope of the gutter-shaped scraper 60 can be adjusted. For instance, with respect to the retrieving device 38 adopting the screw conveyer system, it is possible to have a structure in which the gutter-shaped scraper 60 is supported by a turning axis at its central part in the length direction, so that the gutter-shaped scraper 60 could become swingable like a seesaw using an expansion device such as a cylinder device, etc.

Next, operation of the magnetic separation apparatus 20 structured in the above-described manner is described.

The raw water containing the magnetic flocs F is to enter from the feed-water inlet 44 formed in the lower end of the separation tank 32 and have its flow divided by the flow dividing members 46. By the flow dividing members 46, the flow of the raw water is divided to right and left sides with respect to the surfaces of the continuously rotating magnetic disks 36, and is divided so that the flows go into a ferromagnetic space between each adjacent magnetic disk 36. While the divided raw water flows upwardly within the separation tank 32, the magnetic flocs F in the raw water are adsorbed onto the surfaces of the magnetic disks 36. The treated water which has been purified by having the magnetic flocs F adsorbed onto the magnetic disks 36 overflows into the pair of troughs 40 provided on both right and left sides of the magnetic disks 36.

On the other hand, the magnetic flocs F adsorbed onto the magnetic disks 36 are carried into the air above the surface of the water by the continuous rotation of the magnetic disks 36, and thus they will be exposed to the air. As the magnetic flocs F get exposed to the air, moisture of the magnetic flocs F will run down the surfaces of the magnetic disks 36 into the separation tank 32 due to gravity. Furthermore, the magnetic flocs F adsorbed onto the magnetic disks 36 are consolidated due to the magnetic force of the magnetic disks 36. Thereby, dehydration of the magnetic flocs F is promoted to the extent that they turn into sludge forms with moisture content of about 90%.

The magnetic flocs F with their dehydration being promoted are conveyed by the continuous rotation of the magnetic disks 36 up to where the gutter-shaped scrapers 60 are arranged, they are scraped off by the edge parts 60A of both sides of respective gutter-shaped scrapers 60, and then they drop into the gutter-shaped scrapers 60. The magnetic flocs F being dropped inside the gutter-shaped scrapers 60 are conveyed by the conveying devices 62, which can be the screw conveyers 64 or the finned belt conveyers 66, to the upper side of the floc retrieving tank 42 and drop into the floc retrieving tank 42.

Since the magnetic separation apparatus 20 according to the present invention is provided with the flow dividing members 46 arranged directly underneath the plurality of magnetic disks 36, it is possible to have the magnetic flocs F in the raw water efficiently adsorbed onto the magnetic disks 36.

Moreover, by arranging the sealing plates 48 between the respective magnetic disks 36 and the separation tank 32, the raw water does not short-cut through the peripheral surfaces of those magnetic disks 36 that are not exerting magnetic force and overflow into the troughs 40. Thereby, it is possible to prevent water quality of the treated water overflowing into the troughs 40 from deteriorating.

Furthermore, among the plurality of magnetic disks 36 arranged on the rotation axis 34, the inner magnetic disks 36B are structured as having the same structures as the ones in the conventional art, that is, each of them is structured as having permanent magnet pieces 37 arranged on both sides of the disk substrate 33, whereas with respect to the outmost magnetic disks 36A, each of them is structured as having the permanent magnet pieces 37 for exerting magnetic force arranged only on

the inner side surface of the disk substrate 33 (i.e. the surface on the side of the inner magnetic disk 36B). In addition to that, the disk substrates 33 of the respective outmost magnetic disks 36A with the permanent magnet pieces being arranged are made to have more enhanced stiffness than the disk substrates 33 of the respective inner magnetic disks 36B. In this case, by adopting honey comb structures to the magnetic disks 36, it is possible to have lighter magnetic disks 36 while securing necessary stiffness.

In addition, the shielding members 54 are arranged to fill in the gaps between respective outer surfaces of the outmost magnetic disks 36A and the inner surface of the separation tank 32. Thereby, it is possible to prevent magnetic leakage from the outmost magnetic disks 36A and to prevent the outmost magnetic disks 36A from being deformed. What is more, by this arrangement, the raw water does not pass through the outer surfaces of the respective outmost magnetic disks 36A to flow out into the troughs 40, whereby the water quality of the treated water does not be deteriorated.

Moreover, by adopting gutter-shaped scrapers 60 for the retrieving device 38, it is possible to reliably retrieve the magnetic flocs F adsorbed onto the magnetic disks 36.

While the magnetic separation apparatus of the present invention have been explained in detail, the present invention is not limited to the above examples, needless to say, various improvements and modifications may be added without departing from the scope of the present invention.

## CLAIMS

1. A magnetic separation apparatus, comprising:
  - a separation tank to which raw water containing magnetic flocs is to flow
  - 5 into, the separation tank having a feed-water inlet provided in the lower end of the separation tank for supplying the raw water to the separation tank as an upward flow;
  - a plurality of magnetic disks which adsorb the magnetic flocs by use of magnetic force, the plurality of magnetic disks being arranged at predetermined intervals on a rotation axis provided in the separation tank and being substantially
  - 10 half sunk in the raw water in the separation tank;
  - a retrieving device which retrieves the magnetic flocs adsorbed onto the magnetic disks;
  - flow dividing members, provided directly underneath the respective magnetic disks, which divide the flow of the raw water supplied from the feed-water
  - 15 inlet in right and left directions with respect to surfaces of the magnetic disks and in a thickness direction of the magnetic disks; and
  - a pair of troughs, provided on opposing sides of the separation tank parallel to the rotation axis, where treated water after removing the magnetic flocs from the raw water by the magnetic disks overflows.
- 20 2. The magnetic separation apparatus according to claim 1, wherein the flow dividing member is formed so that the flow dividing member has a thickness at the upper end being the same as a thickness of the magnetic disk, and has a wedge shape at cross section in which the thickness becomes thinner towards the lower end.
- 25 3. The magnetic separation apparatus according to claim 1 or 2, wherein the feed-water inlet is formed in a square tube shape which is longer in the direction of the rotation axis.
4. The magnetic separation apparatus according to any one of claims 1 to 3, further comprising

sealing plates provided between peripheral surfaces of the respective magnetic disks and an inner surface of the separation tank in a way such that base ends of the sealing plates are fixed to the inner surface of the separation tank and apical ends of the sealing plates as being free ends contact the peripheral surfaces of the magnetic disks.

5        5.        The magnetic separation apparatus according to any one of claims 1 to 4, wherein

the retrieving device includes:

10        gutter-shaped scrapers, each of which being provided, in a form of a gutter extending from the vicinity of the rotation axis to the outside of the separation tank, between two adjacent rotating magnetic disks just before entering the raw water from the air, each of the gutter-shaped scrapers having edge parts in the upper ends of both sides contact the surfaces of the magnetic disks with predetermined urging force to scrape off the magnetic flocs adsorbed onto the surfaces of the magnetic disks; and

15        conveying devices provided inside respective gutter-shaped scrapers, each of which conveys the magnetic flocs being scraped off, dropped and accumulated inside the gutter-shaped scraper to the outside of the separation tank.