(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 341 824
A2

(12) # EUROPEAN PATENT APPLICATION

(21) Application number: 89303493.4

(51) Int. Cl.4: B03C 1/02

(22) Date of filing: 10.04.89

The title of the invention has been amended (Guidelines for Examination in the EPO, A-III, 7.3).

(30) Priority: 11.04.88 JP 87372/88
11.04.88 JP 87373/88
11.04.88 JP 87374/88

(43) Date of publication of application:
15.11.89 Bulletin 89/46

(84) Designated Contracting States:
DE FR GB SE

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(54) **Apparatus for magnetic separation of impurities from fluids.**

(57) Disclosed is an apparatus for efficiently effecting a high gradient magnetic separation process. This apparatus for purifying impurities in fluids provides a plurality of filter elements with a frame streched with ferromagnetic linear bodies which are contained in fluid flowpassage in a non-magnetic case, a magnetizing device disposed externally on side walls of the non-magnetic case, and washing means for washing the filter elements, whereby magnetic impurities in the fluid can be capatured efficiently, and backwashing can be easily accomplished.

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APPARATUS FOR PURIFYING IMPURITIES IN FLUIDS

FIELD OF THE INVENTION

The present invention relates to an apparatus for purifying impurities in fluids for performing purification of a coolant used for cold rolling iron and steel, purification of wastewater in an exhaust gas Venturi scrubber in a converter or wastewater treatment in thermal and nuclear power station, and so forth.

PRIOR ART

The technique of high gradient magnetic separation (HGMS) is a method for using wires made of ferromagnet for a filter, which was devised by Kolm et al in 1963 or so (Phys. Rev. 132, 387 - 1963), and thereafter promoted to be studied and developed by M.I.T. early in 1970, since then the aforesaid method has been put for practical use (J.A. Oberteuffer: IEEE Trans. Magn. MAG-9 (3), 303 - 1973).

This principle will be explained. When a magnetic field is applied to a magnetic wire, a magnetic-field gradient occurs in the vicinity of the wire, and a magnetic force exerts on magnetic particles present in the neighbourhood thereof. The magnetic force at that time is expressed by equation (1) for the ferromagnet and expressed by equation (2) for the paramagnetic material.

$F = Is \cdot V \cdot (dH/dx)$ (1)

$F = \chi \cdot H \cdot V \cdot (dH/dx)$ (2)

where,

Is : Saturated magnetization

χ : Susceptibility of particles

V : Volume of particles

H : Strength of magnetic field

dH/dx : Magnetic gradient

In these equations, as operable factors, H relies upon the performance of magnet, and dH/dx relies upon the characteristics of filter material.

Forces resisting to the magnetic force contemplated include a resistance of fluid, a gravity, an inertia force, and so forth. Various magnetic filters such as Kolm type HGMS device have been developed on the basis of the above-described theory. In the Kolm type HGMS device, filter elements formed from stainless steel wool-like fine wires are housed into a closed chamber, which gives rise to a problem in that clogging is liable to occur, and a large quantity of water is required in backwashing.

The backwashing normally means that in order to discharge impurities stayed on the element outside the system, a large quanity of steam and/or hot water in the range of 70 to 90 °C are caused to flow in a direction opposite to that when purification takes place (Refer to Japanese Patent Application Laid-Open Nos. 193617/1987, 19300/1987 and 154705/1986).

Filter elements of the HGMS device being used include stainless steel wires having an amorphous net-like shape of a diameter of approximately 1 mmΦ in view of magnetic characteristic, corrosion resistance and maintenance. The stainless filter composed of such a fine wire is possible to obtain a high magnetic flux density but has a residual magnetism, thus posing a problem in that even if the magnetic field is released, the magnetic particles remain adhered to the filter element and the separation efficiency when the particles are removed is poor.

As the technique for solving such a problem as noted above, a technique which uses an amorphous fine wire has been recently employed. The amorphous fine wire has no residual magnetism, and when the magnetic field is released, the magnetic particles can be separated efficiently. The amorphous fine wire is excellent in corrosion resistance.

However, such a conventional device has the disadvantages that since the arrangement of elements is out of order, the distribution of the elements in a fluid passing section is irregular so that the fluid is liable to flow unevenly; that where it is used for viscous fluid such as rolling oil, clogging tends to occur; and that the fluid resistance becomes high. In addition, the amorphous magnetic material has a magnetic distortion characteristic, which differs with the way of applying stress. Generally, a material as cast improves its magnetic characteristic by applying tension thereto, but if tension is excessively applied, a delay breakdown occurs. By annealing the material, variation of magnetic characteristic and delay breakdown due to the stress can be reduced, but brittleness occurs owing to the annealing, and the annealing leads to an increase of cost.

Furthermore, U.S. Patent No. 4,528,096 discloses a construction in which a flat ribbon made of soft magnetic amorphous alloys is wound spirally or arranged in parallel. However, in this patent, a practical problem involved in an industrial device is not solved, and the patent discloses nothing of demagnetization and backwashing.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an apparatus which achieves an enhancement of performance of removing magnetic particles of a magnetic filter and which is simple and has a high performance.

A further object of the present invention is to reduce a force resisting to a magnetic force, for example, gravity, a fluid resistance and an inertia force, increase strength H of a magnetic field, and employ a large magnetic gradient dH/dx.

The present invention provides an apparatus for purifying impurities in fluids comprising a plurality of filter elements comprising a frame having ferromagnetic linear bodies stretched contained in a fluid flowpassage within a non-magnetic case, a magnetizing device disposed externally on the sides of said non-magnetic case, and a washing means for washing the filter elements.

The present invention is characterized in that a plurality of filter elements in which ferromagnetic linear bodies are contained in a non-magnetic case are dipped into a fluid flowpassage in series and in a manner capable of feeding in a horizontal direction, a magnetizing device is disposed externally on the side walls of the fluid flowpassage, and element inlet and exit portions are respectively provided on either end of said flowpassage.

The present invention further provides an apparatus for purifying impurities in fluids comprising a plurality of filter elements in which ferromagnetic linear bodies contained in a fluid flowpassage in a non-magnetic case are packed in a net bag, a magnetizing device disposed externally on the side walls of said non-magnetic case, means for moving said filter elements or said magnetizing device, and washing means.

Furthermore, an inlet pipe for introducing a washing liquid or gas into a filter chamber, and a supersonic washing device is disposed in said inlet pipe to increase the washing effect.

Moreover, the apparatus according to the present invention comprises a supersonic washing device for transmitting supersonic waves in a filter chamber to render reservoir washing possible to enhance the washing effect.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a view showing a circulating system for a coolant for rolling a steel material;

Fig. 2 illustrates an embodiment according to the present invention, Fig. 2(a) being an elevation view, Fig. 2(b) being a plan view, and Fig. 2(c) being a cross sectional view;

Fig. 3 is an elevation view of a further embodiment according to the present invention;

Fig. 4 illustrates the relationship between a magnetic force and a resistance;

Fig. 5 illustrates a difference in occurence of a magnetic force caused by a sectional shape of a filter fine wire;

Fig. 6 is a schematic longitudinal sectional view of a Kolm type magnetic filter;

Fig. 7 is a partly sectioned side view of a disk type magnetic filter;

Fig. 8 is a longitudinal sectional view of a reciprocating type magnetic filter;

Fig. 9 is a circulation system view of a rolling coolant applied to an embodiment;

Fig. 10 is a schematic side view of an embodiment of an apparatus for purifying impurities in fluids according to the present invention;

Fig. 11 is a perspective view of one element of an amorphous fine wire filter stretched on a frame of an embodiment according to the present invention;

Fig. 12 is a sectional view taken on line A - A of Fig. 1;

Fig. 13 is an external view of a conventional amorphous filter element packed in a bag;

Fig. 14 is a graph showing the relationship between a coercive force and tension of an amorphous line material;

Fig. 15 is a graph showing the relationship between breakdown time and tension of an amorphous wire material; and

Fig. 16 is a graph showing change of a magnetic particle removing factor with time in a comparative example with resepct to the embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

Fig. 1 shows a circulation system view of a coolant for rolling a steel material, which is one example to which the apparatus of the present invention is applied.

When a rolling material 14 is rolled by and passed between rolling rolls 10 and 12, a coolant (rolling oil) 16 is injected out of a nozzle 18. The coolant 16 is returned to tanks 20 and 22 via a pan 28 which receives a falling flow of coolant. The coolant returned to the tanks contains iron powder produced from the rolling material 14 and rolls 10, 12 during rolling, and as an amount of rolling increases, the iron powder contained in the coolant is thickened. When the quantity of iron powder in the coolant increases, deterioration of properties of the surface of rolling material, occurence of flaw on the rolls, slip during rolling and so forth occur.

Therefore, a bypass circuit is provided in a coolant circulation circuit, and a magnetic filter 32 is installed on the bypass circuit to discharge the iron powder in the coolant outside the system. In the case where the coolant is purified in the bypass circuit, the coolant is fed under pressure from a dirty tank 22 by means of a pump 30, passes through a filter 32 and returns to the clean tank 20.

The thus purified coolant is fed under pressure by means of a pump 24, and passes through a mesh filter 26 for use as a mill coolant.

A magnetic filter 32 shown in Fig. 1 uses a Kolm type HGMS device of prior art shown in Fig. 6.

Fig. 6 is a longitudinal sectional view of a typical conventional Kolm type HGMS device 110. This device is of the closed type in which a coil 114 and a yoke 116 are disposed around a filter element 112 formed from a stainless steel wool-like fine wire, a slurry is introduced from an inlet pipe 118, magnetic powder in the slurry is captured by the filter element 112, and liquid from which the magnetic powder is removed is discharged out of an outlet pipe 120. This device is suitable for a low load and a large flow rate.

However, in the case where an oil fluid circuit such as a rolling coolant is used, if a filter element formed from a fine wire for increasing a magnetic gradient (dH/dx) is used, clogging is liable to occur. In practice, a ferrite system stainless wire material having a diameter of a few mmΦ is used, in which the magnetic characteristic is not so well, and for example, permeability is about 120, and the magnetic gradient is limited. In addition, this device is of the closed construction and a layer of the filter element is thick so that when demagnetized, magnetic properties remain, and therefore a large quantity of water is required for backwashing in order to discharge impurities, which leads to a problem in that a large quantity of wastewater is produced.

Figs. 8 (a) and 8 (b) are a cross sectional view and a longitudinal sectional view, respectively, of a further conventional reciprocating type magnetic filter 140 of HGMS. This magnetic filter 140 has magnets 144 disposed on both lateral aides of a filter element 142 which horizontally reciprocates in a lateral direction as viewed in Fig. 8 (a), and a fluid is caused to flow down from an upper fluid inlet 16, passes through a filter element 142 and is discharged out of an outlet 148.

On the other hand, high pressure water for washing the filter element is injected out of a high pressure water pipe 150 to wash the filter element 142, and the water used for washing is discharged out of a washing water outlet 152. A motor 154 causes a filter element to be reciprocated through a conduction device 156, and therefore the filter element alternately performs passing of water and washing (back washing).

In the construction of a magnetic filter shown in Fig. 8, the fluid flows in a direction of gravity, and therefore, gravity resisting to a magnetic force in Fig. 3 acts, and since the flow velocity is accelerated by the gravity, both fluid resistance and inertia force increase. Accordingly, the removing factor of magnetic particles lowers.

Fig. 7 illustrates a disk type magnetic filter 130 comprising a ferromagnetic disk 132 buried with non-magnetic columns 134. At the boundary portions therebetween magnetic impurities are captured by magnetic gradient. The apparatus has only smaller magnetic gradient and lower purifying capacity as compared with those having magnetic wires, and accordingly is used only for rough purification purpose.

Fig. 2 shows an example of the apparatus according to the present invention.

The most important characteristic of the apparatus according to the present invention resides in that a flow of fluid is horizontal. By this arrangement, the gravity resisting to the magnetic force can be removed, and the flow velocity can be controlled to be low due to the flow which includes a gravity acceleration, and the fluid resistance and inertia force can be reduced. Thereby, the magnetic force can be secured efficiently.

Moreover, by making the fluid flow horizontal, a hard magnet or a coil can be placed on the side wall of the fluid passage, and a yoke can be installed on the bottom side of the fluid passage to render possible the increasing of the efficiency of the magnetizing device and the increasing of the strength H of the magnetic field.

Furthermore, for the filter element, a rectangular section of an amorphous fine wire or a ferritic stainless having a rectangular section was used to increase the magnetic gradient dH/dx.

Fig. 4(a) shows a gradient of a magnetic field when a magnetic wire 46 having a circular section is disposed within a magnetic field, in which magnetic particle 41 placed in the neighbourhood thereof is not adsorbed. When a magnetic wire 47 having a rectangular section as shown in Fig. 4(b) is disposed, the gradient of the magnetic field becomes large, particularly, the gradient of the magnetic field in a rectangular corner portion becomes large, in which magnetic particle 41 not adsorbed in Fig. 4(a) is adsorbed.

Fig. 2 (a), Fig. 2(b) and Fig. 2(c) show one example of the present invention, Fig. 2(a) being a longitudinal sectional view, Fig. 2(b) being a plan view, and Fig. 2(c) being a cross sectional view.

A plurality of filter elements 42 in which ferromagnetic linear bodies are contained in a non-magnetic case are dipped in series into a fluid which flows horizontally within a fluid flowpassage 46, and magnets 48, 50 and a yoke 52 are used to apply a magnetic field thereto from a side wall of the fluid flowpassage 46 so that magnetic impurities in the fluid are adhered to the filter elements 42.

The apparatus is characterized in that the filter elements 42 washed are charged at a downstream of the flow in the fluid flowpassage 46 in a cycle depending upon conditions of the concentraction of magnetic impurities, flow rate of fluids and the like, and the filter elements 42 adhered with the magnetic impurities and deteriorated with ability are discharged from the fluid flowpassage by a pusher system to control the distribution of the impunity concentration of the filter elements in the fluid in a flowing direction of the fluid flowpassage.

The charge and dicharge of the filter elements 42 are carried out by arms 64, 66 mounted on a carriage 62 which travels above the fluid flowpassage. The filter elements discharged out of the fluid flowpassage are carried to an inlet 56 of a purifying device 54 and then washed by a high pressure steam or a jet from a high pressure and hot water header 70. The magnetic impurities pass through a discharge duct 72 and are moved out the system. The washed filter elements 44 are taken out from an outlet 58 of the purifying device and then again charged into the fluid flowpassage.

According to this system, the fluid resistance, gravity, inertia force and the like acting on the magnetic impunity particles can be reduced as compared with the conventional device, and therefore, less elements of impeding the magnetic force of the ferromagnetic filter elements acting on the magnetic impurities are present, thus increasing the factor of removing the magnetic impurities.

An embodiment shown in Fig. 3 is of a suspension system in which filter elements 42 are suspended on a suspension device, and part of the suspended filter elements of the suspension device is charged into and discharged out of the fluid. The filter elements 42 are moved by suspension arms 76 which travel along a suspension rail 74. When the filter elements 42 pass through the fluid flowpassage 46, they travel along a lower suspension rail 74 and are dipped into the fluid flowpassage to adsorb magnetic impurities on the filter elements. Next, during the travelling along a higher suspension rail, the magnetic impurities stay away from the magnetic field and therefore the impurities are easily removed by the washing liquid from a magnetic impunity washing header 80, recovered by an discharge duct 78 and discharged outside the system.

In the apparatus shown in Fig. 3, washing devices 80 and 82 are arranged at the front and rear of the dipping portion, and magnetic impurities within the fluid can be always removed with high efficiency by reciprocating a moving device 84. If the moving device 84 is formed from an endless mode, one washing device 80 will suffice and there is one moving direction.

The aforesaid ferromagnetic linear body may be formed of amorphous metal having a rectangular section whose width is 0.5 to 5 mm and thickness is 10 to 50 #m, and the aforesaid magnetizing device is formed from a hard magnet.

Or, the aforesaid ferromagnetic linear body may be formed of ferrite system stainless having a rectangular section whose width is 0.5 to 5 mm and thickness is 10 to 50 µm, and the aforesaid magnetizing device may be formed from an electromagnet, of course.

It is noted that if a plurality of fluid flowpassages are arranged in parallel with each other, and inlet and outlet aides of the fluid flowpassages are brought into communication with each other, the fluid flowpassages being arranged in parallel, a device having a large handling capacity can be obtained.

Fig. 9 shows the entire construction as one example of a conventional HGMS device, in which a filter element 170 is contained in a filter case, which is magnetized by an empty core coil 172 externally disposed. A liquid 174 to be purified enters from an inlet, passes through the filter element 170 and is discharged from an outlet 176. During that stage, a ferromagnet and strong paramagnetic material as impurities within the treating liquid are magnetically adsorbed by the filter element 170 and removed.

When the quantity of adsorption increases, the removing factor lowers and the pressure loss increases, in which case, valves 162 and 166 are closed, the magnetic field of the empty core coil 172 is stopped, and valves 164 and 168 are opened so that a backwash liquid 178 is introduced through the inlet and backwashed, and caused to pass through the filter element 170 and discharged from the outlet 180, whereby the impurities adhered to the filter element 170 can be removed.

It is noted that a treating liquid is caused to pass through a separate magnetic filter during the backwashing so that the former may be treated at all times.

Amorphous metal is excellent in characteristics such as magnetic characteristic, corrosion resistance and strength. Accordingly, if this is used in place of a ferritic stainless wire material so far used as a filter material, it is possible to design a magnetic filter working efficiently.

Table 1 shows a comparison of permeability and coercive force between ferritic stainless filter and amorphous metal filter, in which the permeability of the amorphous metal is better by 10^2 times than that of the ferritic stainless steel. That is, the amorphous metal is easily magnetized even in the low magnetic field, and the magnetic force can be applied to a magnetic suspended matter. Thereby, the magnetizing device can be formed from an electromagnet to a hard magnet. The residual magnetization is substantially the same therebetween, but backwashing can be easily performed because the coercive force is small.

Table 1

	Ferritic stainless filter	Amorphous filter
Permeability	500	15,000
Coercive force Hc (Oe)	1.2	0.3

Fig. 10 shows an embodiment of an impunity purifying apparatus according to the present invention, in which a hard magnet is used as a magnetizing device, which is mechanically moved. In Fig. 10, the hard magnet is moved to a position indicated at 188.

Thereby, an amorphous filter 182 can be simply magnetized or demagnetized.

In backwashing, steam or hot water is used to wash the filter as in prior art. A header 184 of a supersonic washing device is provided at an upstream of a backwash flow to enhance the washing effect, not to increase the flow rate of the backwash flow, reduce the flow rate, and reduce the backwash time and wastewater.

As a method for promoting this, the impurities have been flown away by the high speed flow of the backwash in prior art, but in this invention, the supersonic washing is employed so that washing can be carried out even in a still flow. Thereby, valves 162 to 168 are totally closed and reservoir washing is carried out by supersonic waves whereby the quantity of wastewater can be minimized. It is extremely preferable to reduce the quantity of wastewater because the wastewater brings forth the secondary pollution.

Furthermore, with respect to the backwashing, a supersonic washing device is directly mounted in a filter chamber or provided on a washing liquid or gas introducing pipe to reduce or stop the flow rate of a backwash flow so that washing can be made. With this, the backwashing time can be reduced, and the discharge of wasteliquid can be extremely reduced.

Fig. 11 shows a sheet of element of a filter in which an amorphous fine wire is stretched on a frame, in which an amorphous fine wire 192 is stretched on a frame 190 with adequate tension.

Fig. 12 is a view taken on line XII-XII of Fig. 11, showing a construction of a holding portion for a frame 190 for holding an amorphous fine wire. The frame 190 has an iron core 194 surface of which is wound by a buffer rubber 196 in order that a local stress is not applied to the amorphous fine wire 192. The amporphous fine wire 192 is wound about the frame 190 with fixed tension, outer portion of which is stopped by a fine wire holder 198.

This will be further described in detail.

(1) In the case where a conventional stainless wire material is used as a filter, the coercive force is large. In order to solve this point, an amorphous fine wire having a small coercive force is used.

(2) In the case where an amorphous fine wire is put in a net bag for use as in prior art, an amorphous fine wire is stretched on a holding frame, which is used as a laminate in order to solve an occurrence of a lowering in the removing factor due to clogging, one-aided flow of fluid and the like. In this case, it is desirable that the spacing of amorphous fine wires is disposed in a uniformly mesh-like fashion. Any suitable shape of opening of meshes can be used. The dimension, shape and material of the holding frame may be determined according to the shape and dimension of a filter chamber of a magnetic separator, space density of the amorphous fine wire, kind of fluids and the like. The laminating direction of the frame may be of the direction perpendicular to the flow of fluid passing through the filter or the direction parallel thereto.

(3) A magnetic amorphous has two aspects, one for enhancement of characteristic due to tension and the other for delay breakdown. In order to solve this, adequate tension is set in stretching an amorphous fine wire. Preferably, this tension is in the range from 0.5 to 2.0 kgf/mm^2.

Filter elements having such a constrcution as described above are laminated and put into a filter case shown in Fig. 9 for use as a filter 170.

Fig. 13 shows a conventional filter in which a bulbous amorphous fine wire 202 is put into a net bag 200. This is also used as a filter 170 put into a case shown in Fig. 9 similar to the embodiment.

Tables 1 and 2 show the characteristics of the amorphous net bag and amorphous frame-stretched filter compared with conventional SUS430 wire material. As can be seen from Tables 1 and 2, the amorphous fine wire is magnetically improved over the conventional SUS material, and by the provision of the streching on the frame, the lowering of rigidity and the increase in fluid resistance which have been noted as disadvantages of the amorphous fine wire were improved.

Problems such as a change in magnetic characteristic, a delay breakdown or the like occur depending on the way of application of tension in case where an armorphous fine wire is stretched on a frame. With respect to the magnetic characteristic, material as cast as shown in Fig. 14 is somewhat high in coercive force but the latter assumes a constant value when tension is in excess of 0.5 kgf/mm^2. When tension is less than 2 kgf/mm^2, the delay breakdown of the amorphous fine wire caused by tension will not occur as shown in Fig. 15.

Therefore, suitable tension is from 0.5 to 2.0 kgf/mm^2.

Table 2

Filter element	Coercive force HC (Oe)	Saturate magnetic flux density Bs (KG)	Permeability
SUS 430 1mmϕ wire	1.2	18.0	500
Amorphous metal fine wire, in a net bag	0.3	13.0	12000
Amorphous metal fine wire, streched on a frame	0.25	13.0	13000

Table 3

Filter element	Corrosion resistance	Tensile strength	Rigidity	Fluid resistance * (Kgf/cm^2)
SUS 430 1mmϕ wire	○	50	○	0.3
Amorphous metal fine wire, in a net bag	○	300	×	0.6
Amorphous metal fine wire, streched on a frame	○	300	○	0.3
Note:				

* Value under the same operating condition and when the removing factor of Fe is the same

Embodiment - 1

Apparatus of Fig. 2 is used in a rolling coolant circulation circuit using a synthetic ester coolant, and an experiment was conducted, which will be described below.
Filter material: $Co_{70}Fe_{5}Si_{15}B_{10}$ (Atom %) amorphous
Sectional shape of a filter fine wire: 0.8 mm width x 0.02 mm thickness
Permeability of filter: 15 000
Magnetized magnet: Al -Ni - Co hard magnet
Strength of generated magnetic field: 2KOe
Quantity of coolant treatment: 30 m^3/hr
Temperature of coolant: 50 - 70 °C
Backwash: High pressure steam, 30 sec.
Quantity of generated iron powder: 400 g/hr
Distribution of grain size of generated iron powder:

Grain size:	Proportion (wt.%)
>32 µm	23.9
8 - 32 µm	28.2
1 - 8 µm	10.9
<1 µm	37.0

SS - Fe magnetized : 18 emu/g
SS magnetized: 1.5 emu/g
Operation was carried out under the above-described conditions.

Embodiment - 2

The experiment was conducted using apparatus shown in Fig. 3 and under the same conditions as in Embodiment 1.

Comparative Example - 1

Using the conventional Kolm type magnetic filter shown in Fig. 6, operation was carried out under the following conditions:
Filter material: Ferrite system stainless (SUS430)
Diameter of filter wire: 1 mmΦ
Permeability of filter: 500
Magnetized magnet: Electromagnet
Strength of generated magnetic field: 4KOe
Backwash: Steam was passed for 5 minutes, and thereafter hot water at 90 °C at the rate of 10 m3/min. was passed for two minutes. Other conditions are the same as in Embodiment 1.

Comparative Embodiment - 2

An experimental machine having a function similar to Fig. 8 was used, and the same experimental conditions as those of Embodiment 1 were used.

Comparative Embodiment - 3

In Embodiment 1, a filter fine wire having a circular section of 0.13 mm was used.

Embodiment - 3

Experiment was conducted under the following conditions.
Filter material: Ferrite system stainless (SUS 430)
Sectional shape of filter fine wire:
1 mm width x 0.03 mm thickness
Permeability of filter: 500
Magnetized magnet: Electromagnet
Strength of generated magnetic field: 4KOe
Other conditions were the same as those of Embodiment 1.

Comparative Embodiment - 4

In Embodiment 3, a sectional shape of a filter fine wire was 0.5 mmΦ.

Table 4 shows the removing factor of iron powder and oil take-out ratio in the above-described Embodiments 1 - 3 and Comparative Embodiments 1 - 4.

As will be apparent from Table 4, in the embodiment, the force resisting to the magnetic force when the magnetic impunity was removed from the fluid was removed; the strength of the magnetic field was strengthened; and a rectangular cross sectional element was used to increase the magnetic gradient whereby the high removing factor of iron powder particles and low oil take-out ratio were obtained.

According to the present invention, the removing factor of the magnetic impurities in the fluid is enhanced, the quantity of wastewater treatment can be reduced, and the energy is saved.

Table 4

	Removing factor of iron powder *1 at 100 ppm (%)	Oil take-out ratio *2
Embodiment 1	60	1.8
2	62	1.8
3	67	2.3
Comparative Embodiment 1	18	2.5
2	25	5.1
3	43	2.2
4	50	2.3

*1 Removing factor of iron powder =

$$\frac{\text{Solution iron concentration - treating liquid iron concentration}}{\text{Solution iron concentration}}$$

*2 Oil take-out ratio =

$$\frac{\text{Weight of oil on filter at backwash}}{\text{Weight of iron on filter at backwash}}$$

Embodiment - 4

In the rolling coolant system shown in Fig. 1, the impunity purifying apparatus shown in Fig. 9 was used as the magnetic filter 32.
Filter material: $Co_{70}Fe_5Si_{15}B_{10}$ (at. %) amorphous
Sectional shape of filter wire: 0.8 mm x 0.02 mm
Permeability of filter: 15. 000
Magnetized magnet: Nd - Fe - B hard magnet
Supersonic exciting frequency: 800 kHz
Backwash: 70° C hot water, 3 m3 30 seconds.
The results are as shown in the present system 1 in Table 2.

Embodiment - 5

In the Embodiment 4, at the backwash, the valves 162, 164, 166 and 168 were closed to employ the reservoir washing system, and the result of washing was shown in the present system II in Table 2.

Comparative Embodiment - 5

In the rolling coolant system of Fig. 1, the conventional impunity purifying apparatus shown in Fig. 9 was used.
Filter material: Ferrite system stainless (SUS430)

Diameter of filter wire: 1.5 mmΦ
Permeability of filter: 500
Magnetizing magnet, electromagnet: maximum 4 KOe
Backwash: Steam for five minutes and thereafter 70° C hot water at the rate of 3.5 m^3 for 30 seconds.
The result was shown in the conventional method in Table 2.
The removing factor of iron powder in Table 2 is given by:

$$\text{Removing factor of iron powder} = \frac{\text{Solution iron concentration} - \text{treating liquid iron concentration}}{\text{Soultion iron concentration}}$$

The oil take-out ratio is given by:

$$\text{Oil take-out ratio} = \frac{\text{Weight of oil on filter at washing}}{\text{Weight of iron on filter at washing}}$$

As will be apparent from Table 2, in the present invention, good filter effect was obtained, and the quantity of oil take-out was reduced.

Table 5

	Conventional method	Present system I	Present system II
Removing factor of iron powder *1 at 100 ppm (%)	18	32	32
Oil take-out ratio *2	2.5	1.2	1.2
Quantity of backwash wastewater (m^3/time)	3.5	3	0.5
Backwash time (min.)	5	0.5	1

*1 Removing factor of iron powder =

$$\frac{\text{Solution iron concentration} - \text{treating liquid iron concentration}}{\text{Solution iron concentration}}$$

*2 Oil take-out ratio =

$$\frac{\text{Weight of oil on filter at washing}}{\text{Weight of iron on filter at washing}}$$

With the above-described arrangement, the impunity purifying apparatus according to the embodiment has the following excellent effects:

a) Since the magnetic characteristic of the filter wire material is good, a hard magnet can be used as a magnetized magnet, the backwashing is simple and is done with high efficiency, and the initial and running costs are low.

b) When the present apparatus is used to purify the rolling coolant, the enhancement of cold rolling properties, the enhancement of foil rolling properties, the energy saving and the low pollution can be easily achieved.

Embodiment 5

A corrosion resisting amorphous alloy, $Fe_{76}Cr_2Si_{10}B_{12}N_{12}$ (at. %) was formed into a fine wire by use of a rotational underwater spinning method and stretched on a frame with tension of 1.5 kgf/mm^2 to obtain a filter element shown in Fig. 11.

As a comparative material, a filter was used in which a wire made of SUS430 having a diameter of 1 mmΦ heretofore used was formed into a bulbous configuration shown in Fig. 13.

The conditions of treatment are as follows:

Treating liquid: Rolling coolant (synthetic ester)
Liquid temperature: 60 °C
Quantity of Fe generated: 50 g/hr
Quantity of treated liquid: 1.7 m^3/hr Grain distribution of Fe generated:

>32 µm	25 wt%
32 - 8 µm	50 wt%
8 - 1 µm	20 wt%
<1 µm	5 wt%

Inside diameter of filter case: 0.2 mmΦ
Strength of magnetic field: 3KOe

The result of comparative experiment under the above-described conditions is shown in Fig. 16. In the SUS wire material, clogging occurs shortly, and the removing factor lowers, and therefore washing should be done in a short period of time. In the present invention, the removing factor was maintained for a long period of time. If backwashing is carried out, the removing factor is enhanced as compared with the case of the net bag.

Embodiment 6

An amorphous component of $Co_{70}Fe_5Si_{15}B_{10}$ (at.%) was formed into a fine web by a single roll method using a round-hale nozzle having a diameter of 0.8 mmΦ.

An amorphous fine wire was stretched on the frame shown in Fig. 11 under the same conditions as those of the embodiment to obtain a filter element. The same treating liquid, filter case, strength of magnetic field and the like as those of the embodiment were used for experiment.

As a comparative example, a filter in which the same amorphous fine wire was formed into a bulbous configuration as shown in Fig. 13 which is put into a net bag was used for experiment under the same conditions.

The result obtained therefrom is shown in Fig. 16. It is apparent that in the case of the embodiment, the removing factor is maintained for a longer period of time.

The filter used for the conventional HGMS has been principally formed from a wire material of SUS 430 system which is not good in magnetic characteristic. Recently, attention has been paid to stainless fine wires and amorphous fine wires. However, the bulbous assemblies are insufficient in performances such as rigidity, pressure loss, and maintenance properties, and synthetic appraisal is not yet done.

The present invention provides a novel magnetic filter which has enhanced these perfomances as noted above and has the effect of remarkably enhancing the filter efficiency and further enhancing the characteristics of HGMS.

Claims

1. An apparatus for purifying impurities in fluids comprising:
a plurality of filter elements composed of a frame attached with streched ferromagnetic linear bodies, which are contained in a fluid flowpassage in a non-magnetic case;
a magnetizing device disposed externally of side walls of said non-magnetic case; and
washing means for washing said filter elements.

2. The apparatus according to Claim 1, wherein the plurality of filter elements in which said ferromagnetic linear bodies are contained in a non-magnetic case are dipped into the fluid flowpassage in series and capable of being fed horizontally, the magnetizing device is disposed externally on the side walls of said fluid flowpassage; and inlet and exit portions for said elements are provided on either end of said fluid flowpassage.

3. The apparatus according to claim 2, wherein a pusher for horizontally feeding the plurality of filter elements is provided, and a laterally moving carriage which moves between said element inlet and exit portions and the washing device is provided.

4. The apparatus according to claim 2, wherein a multiplicity of plural filter elements are suspended in series on a suspension device, and a moving device for moving a row of said elements internally and externally of the fluid flowpassage is provided.

5. The apparatus according to claim 2, wherein said magnetizing device is formed from an electromagnet, and said ferromagnetic linear bodies are composed of ferritic stainless steel having a rectangular section.

6. The apparatus according to claim 2, wherein a plurality of fluid flowpassages are disposed, which are connected at inlet and outlet ends thereof respectively.

7. The apparatus according to claim 1, wherein a hard magnet capable of moving away from said non-magnetic case is provided externally of said non-magnetic case, and an introducing pipe for introducing washing liquid or gas into said non-magnetic case is provided.

8. The apparatus according to claim 7, wherein a supersonic washing device is disposed on said introducing pipe.

9. The apparatus according to claim 1, 2 or 7, wherein said magnetizing device comprises a hard magnet, and siad ferromagnetic linear bodies are composed of amorphous metal having a rectangular section.

10. The apparatus according to claim 1, 2 or 7 wherein said ferromagnetic linear bodies are attached with streching tension of 0.5 to 2.0 kgf/mm^2.

11. An apparatus for purifying impurities in fluids comprising:
a plurality of filter elements packed with ferromagnetic linear bodies in a net bag which are contained in a fluid flowpassage within a non-magnetic case;
a magnetizing device disposed externally on the side walls of said non-magnetic case;
means for moving said filter elements or said magnetizing device; and
washing means for washing said filter elements.

12. The apparatus according to claim 11, wherein the plurality of filter elements in which said ferromagnetic linear bodies are contained in the non-magnetic case are dipped into the fluid flowpassage in series and capable of being fed horizontally, the magnetizing device is disposed externally on the side walls of said fluid flowpassage, and inlet and exit portions for said elements are provided on either end of said fluid flowpassage.

13. The apparatus according to claim 11 or 12, wherein a pusher for horizontally feeding the plurality of filter elements is provided, and a laterally moving carriage which moves between said element inlet and exit portions and the washing device is provided.

14. The apparatus according to claim 11 or 12, wherein a multiplicity of plural filter elements are suspended in series on a suspension device, and a moving device for moving a row of said elements internally and externally of the fluid flowpassage is provided.

15. The apparatus according to claim 11 or 12, wherein said magnetizing device comprises an electromagnet, and said ferromagnetic linear bodies are composed of ferritic stainless steel having a rectangular section.

16. The apparatus according to claim 11 or 12, wherein a plurality of fluid flowpassages are disposed, and inlets and exits of the flowpassages are connected respectively.

17. The apparatus according to claim 11 or 12, wherein a pusher for horizontally feeding the plurality of filter elements is provided, a laterally moving carriage which moves between said element inlet and exit portions and the washing device is provided, a multiplicity of said elements are suspended in series on the suspension device, and a moving device for moving a row of said elements internally and externally of the fluid flowpassage is provided.

18. The apparatus according to claim 11 or 12, wherein a pusher for horizontally feeding the plurality of filter elements is provided, a laterally moving carriage which moves between said element inlet and exit portions and the washing device is provided, said magnetizing device comprises an electromagnet, and said ferromagnetic linear bodies are composed of ferritic stainless steel having a rectangular section.

19. The apparatus according to claim 11 or 12, wherein a pusher for horizontally feeding the plurality of filter elements is provided, a laterally moving carriage which moves between said element inlet and exit portions and the washing device is provided, a plurality of fluid flowpassages are disposed, and the inles and exits of the flowpassages are connected respectively.

20. The apparatus according to claim 11 or 12, wherein a pusher for horizontally feeding the plurality of filter elements is provided, a laterally moving carriage which moves between said element inlet and exit portions and the washing device, a multiplicity of said elements are suspended in series on the suspension device, a moving device for moving a row of said elements internally and externally of the fluid flowpassage is provided, and said magnetizing device comprises an electromagnet and said ferromagnetic linear bodies are composed of ferritic stainless steel having a rectangular section.

21. The apparatus according to claim 11 or 12, wherein a pusher for horizontally feeding the plurality of filter elements is provided, a laterally moving carriage which moves between said element inlet and exit portions and the washing device, a multiplicity of said elements are suspended in series on the suspension

device, a moving device for moving a row of said elements internally and externally of the fluid flowpassage is provided, and a plurality of fluid flowpassage are disposed, and the inlets and exits of the flowpassages are connected respectively.

22. The apparatus according to claim 11 or 12, wherein a pusher for horizontally feeding the plurality of filter elements is provided, a laterally moving carriage which moves between said element inlet and exit portions and the washing device, a multiplicity of said elements are suspended in series on the suspension device, a moving device for moving a row of said elements internally and externally of the fluid flowpassage is provided, said magnetizing device comprising an electromagnet and said ferromagnetic linear bodies being composed of ferritic stainless steel having a rectangular section, and a plurality of fluid flowpassages are disposed and the inlets and exits of the flowpassages are connected respectively.

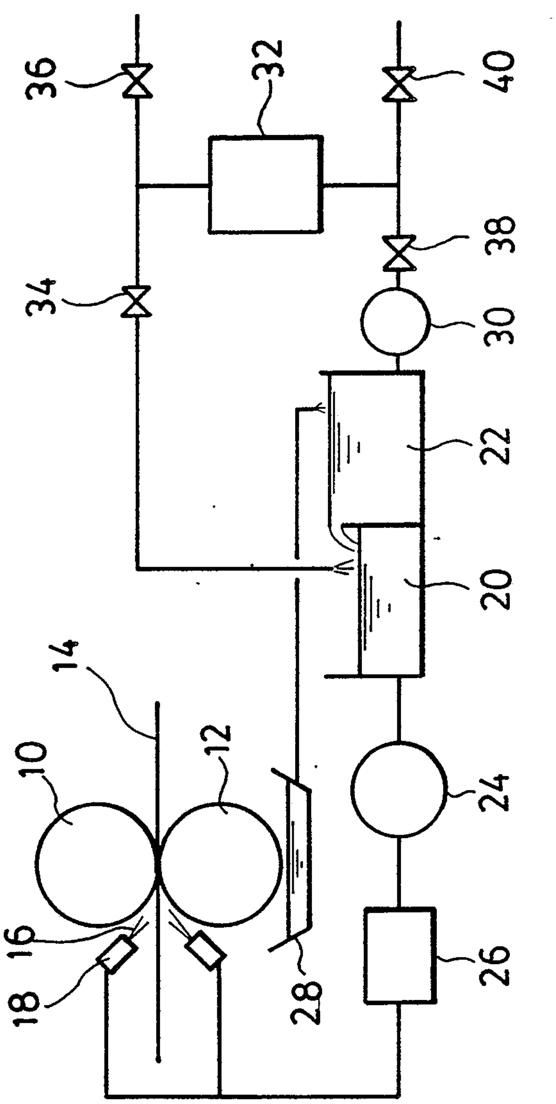


FIG.1

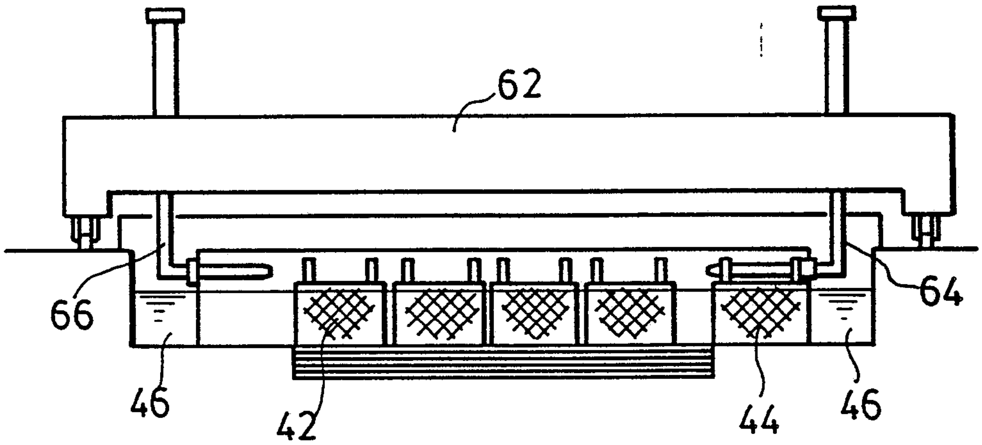


FIG.2(a)

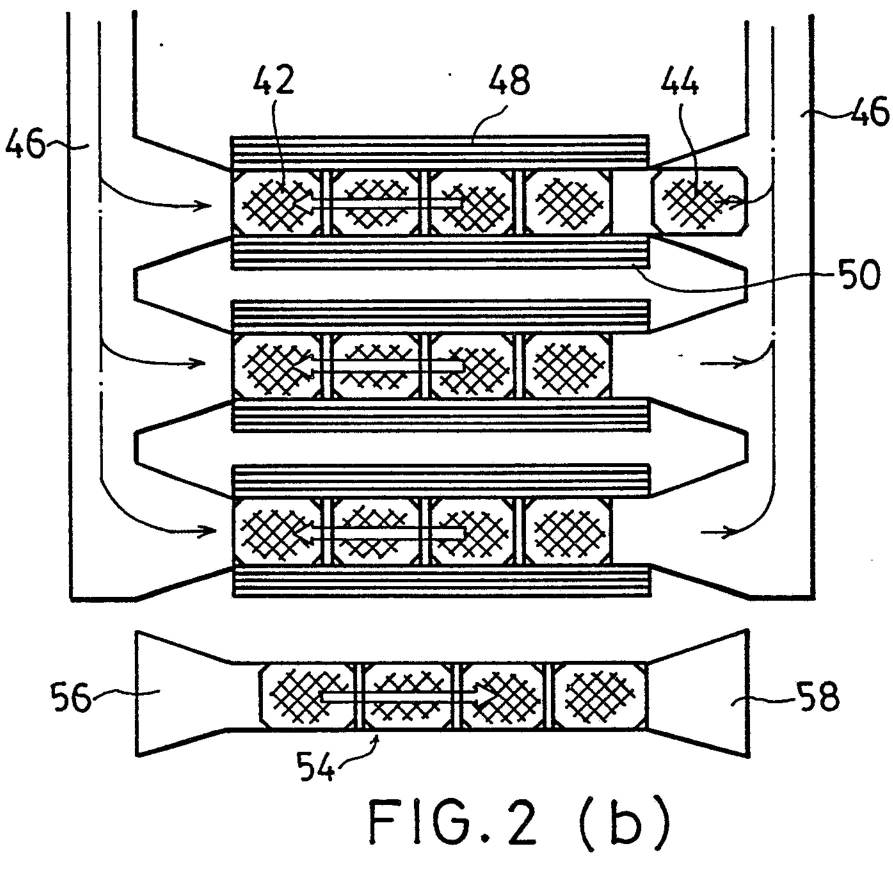


FIG.2 (b)

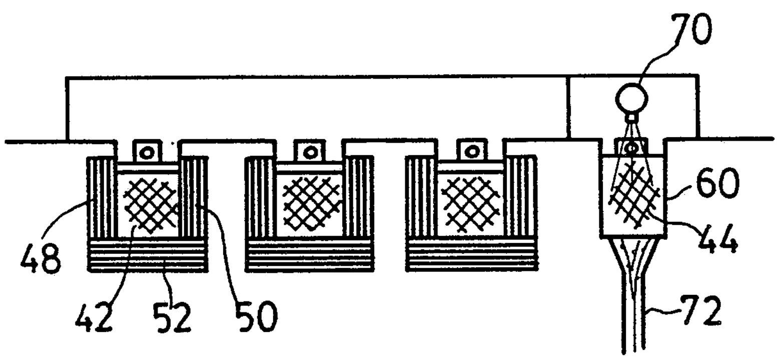


FIG.2 (c)

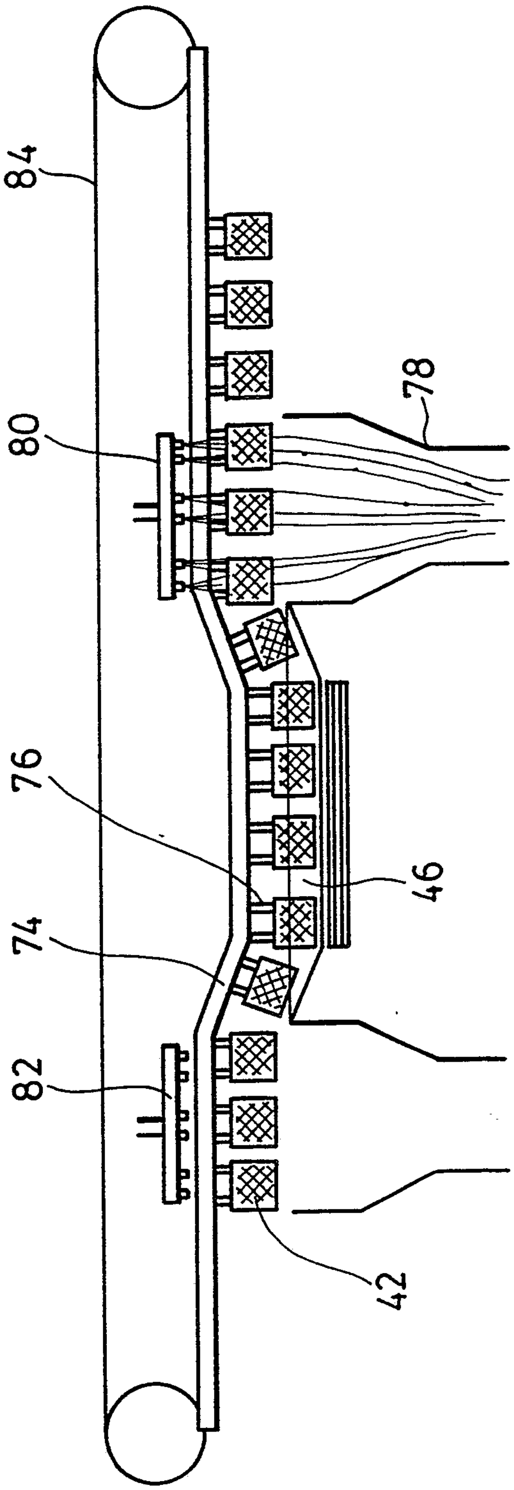


FIG. 3

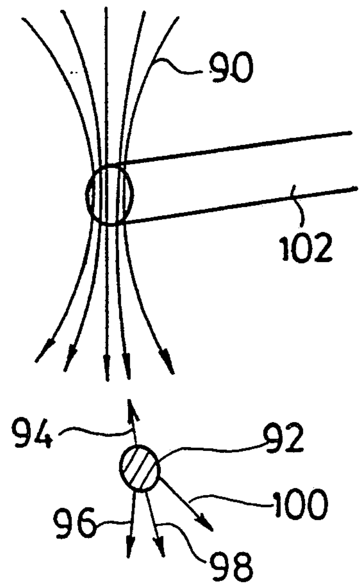


FIG.4

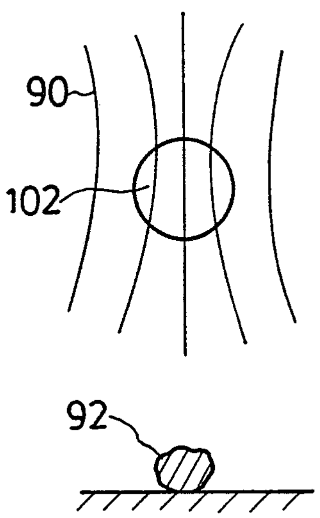


FIG.5 (a)

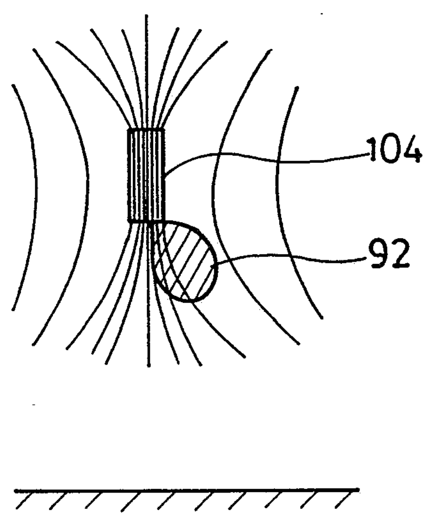


FIG.5 (b)

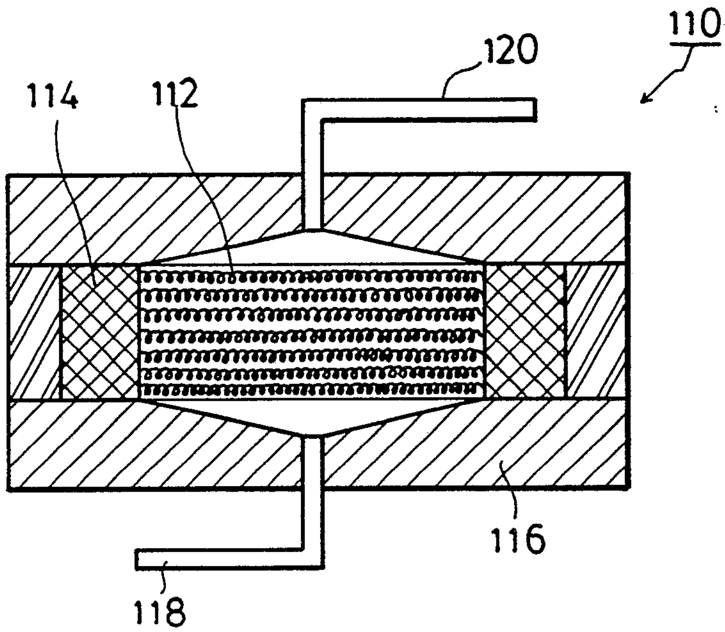


FIG. 6 PRIOR ART

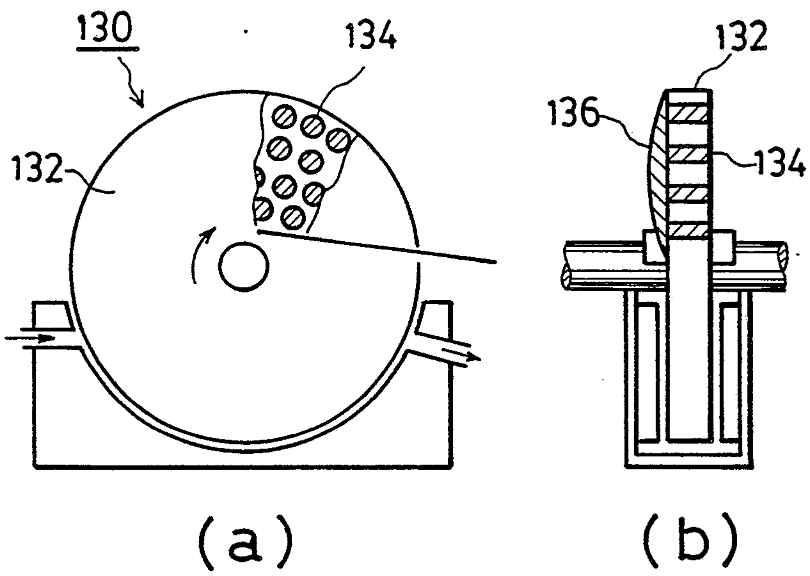


FIG. 7 PRIOR ART

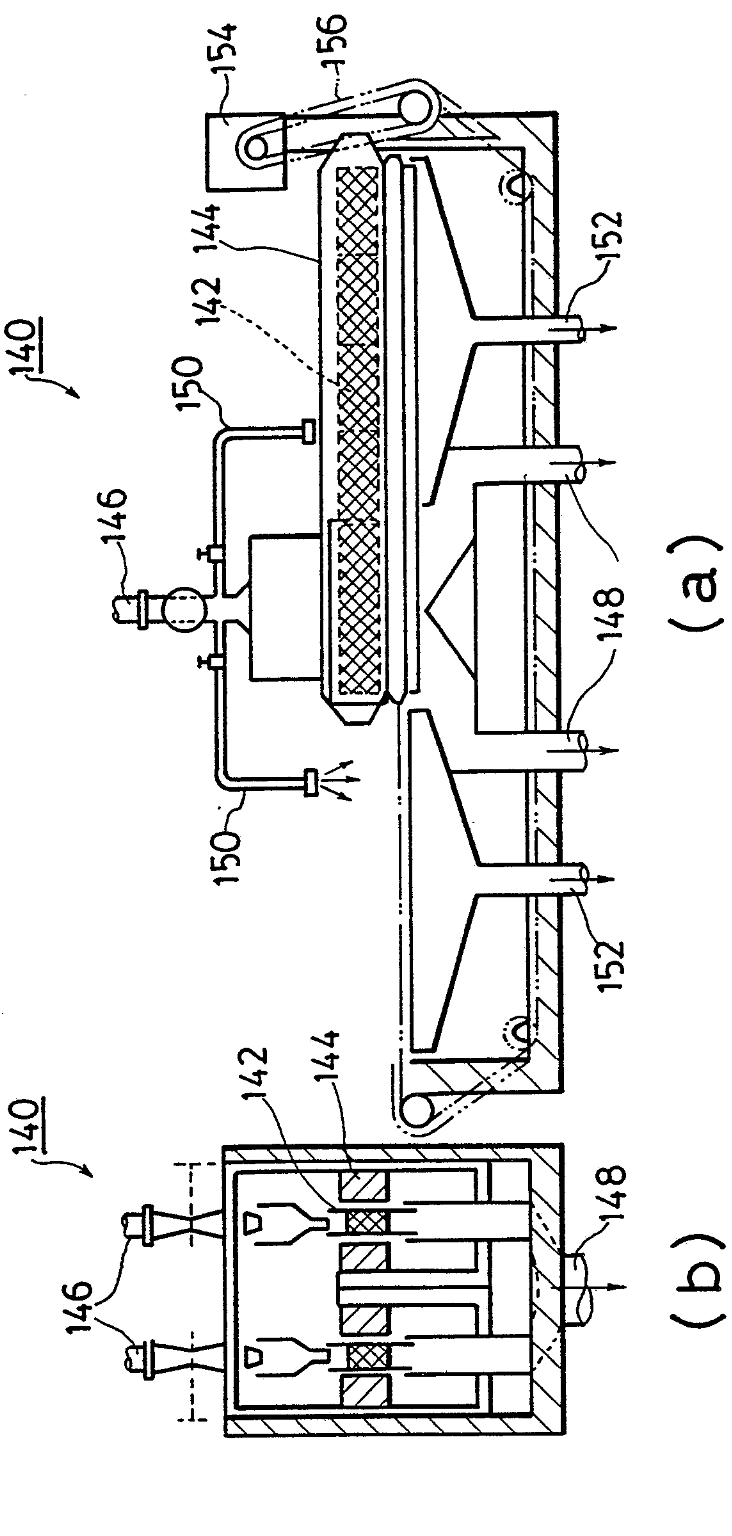


FIG.8 PRIOR ART

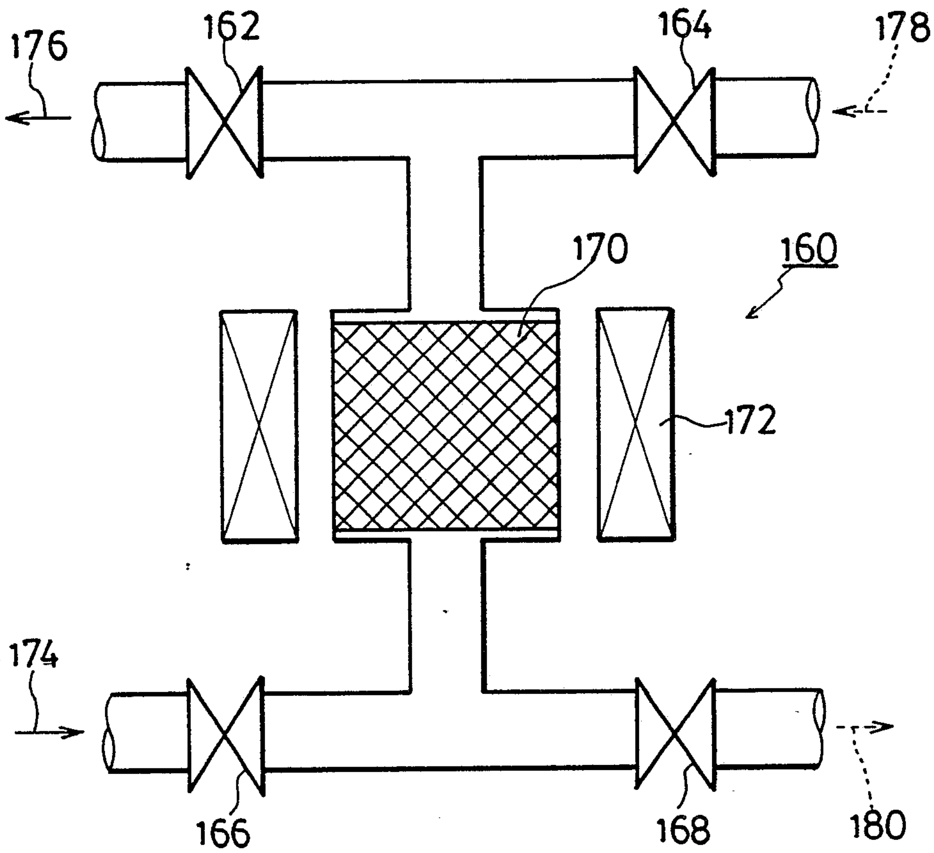


FIG.9 PROIR ART

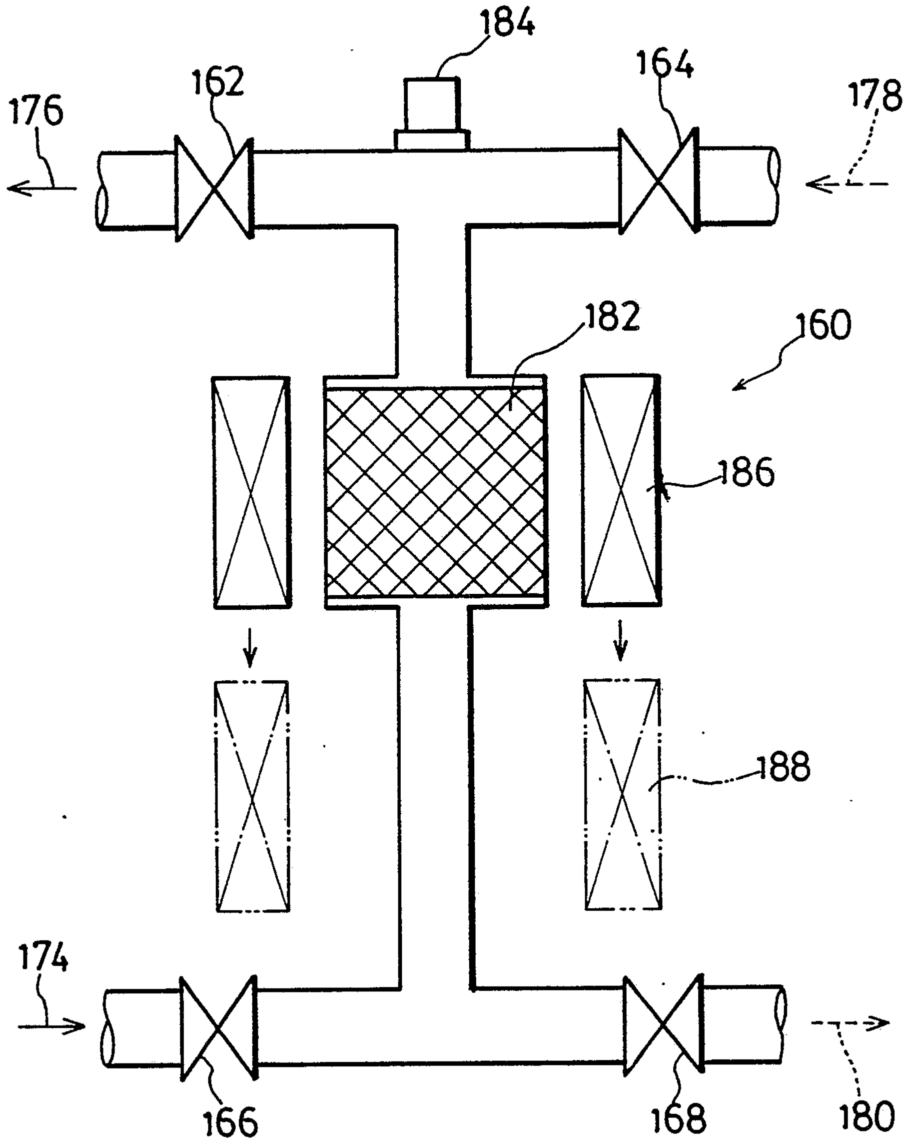


FIG.10

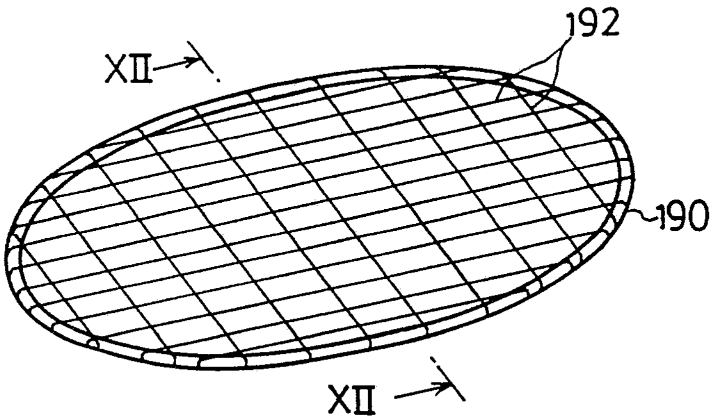


FIG.11

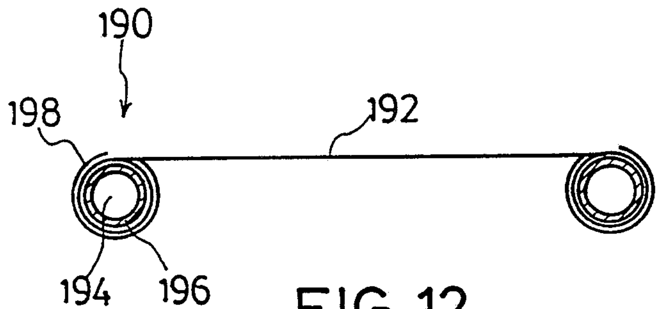


FIG.12

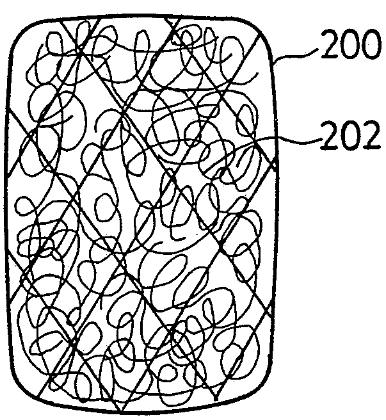
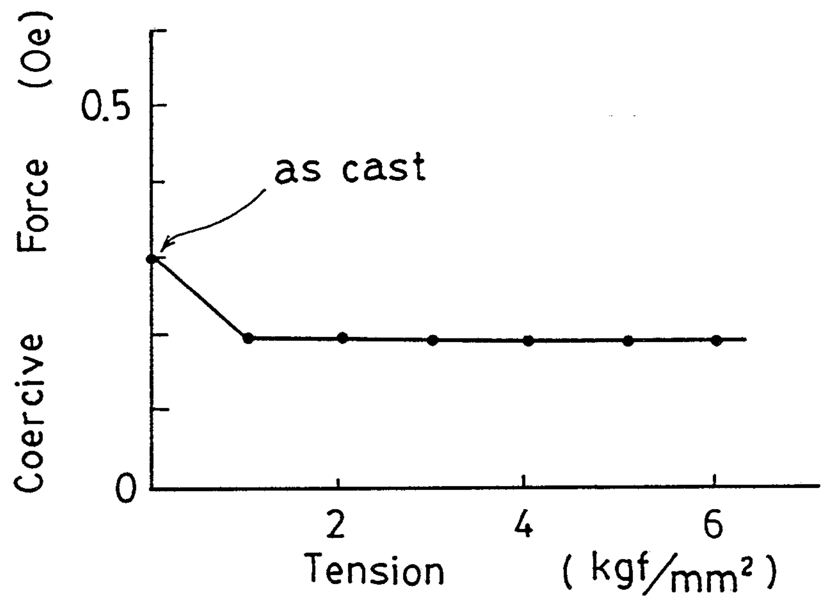
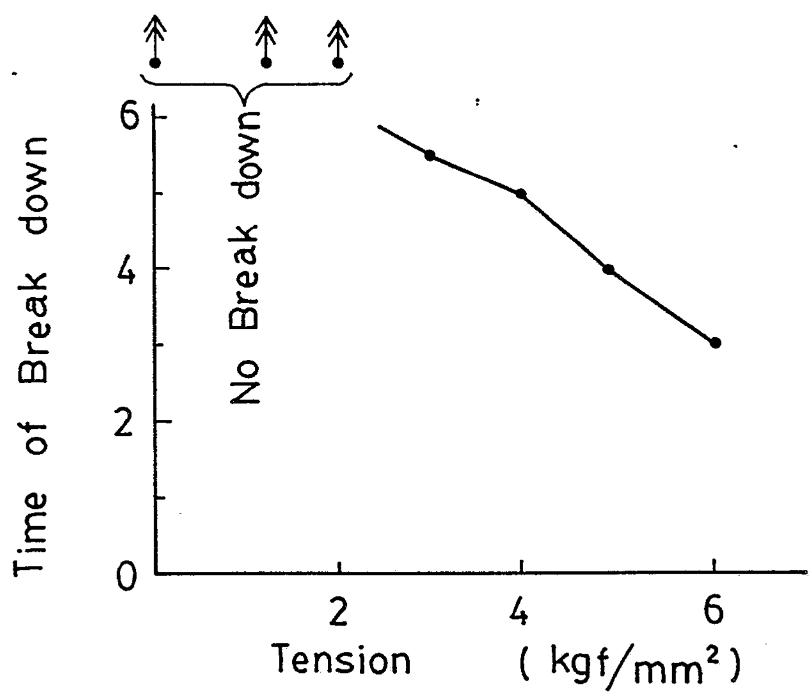


FIG.13



Coercive Force (Oe)
0.5
0
as cast
2
4
6
Tension (kgf/mm²)

FIG.14



Time of Break down
6
4
2
0
No Break down
2
4
6
Tension (kgf/mm²)

FIG.15

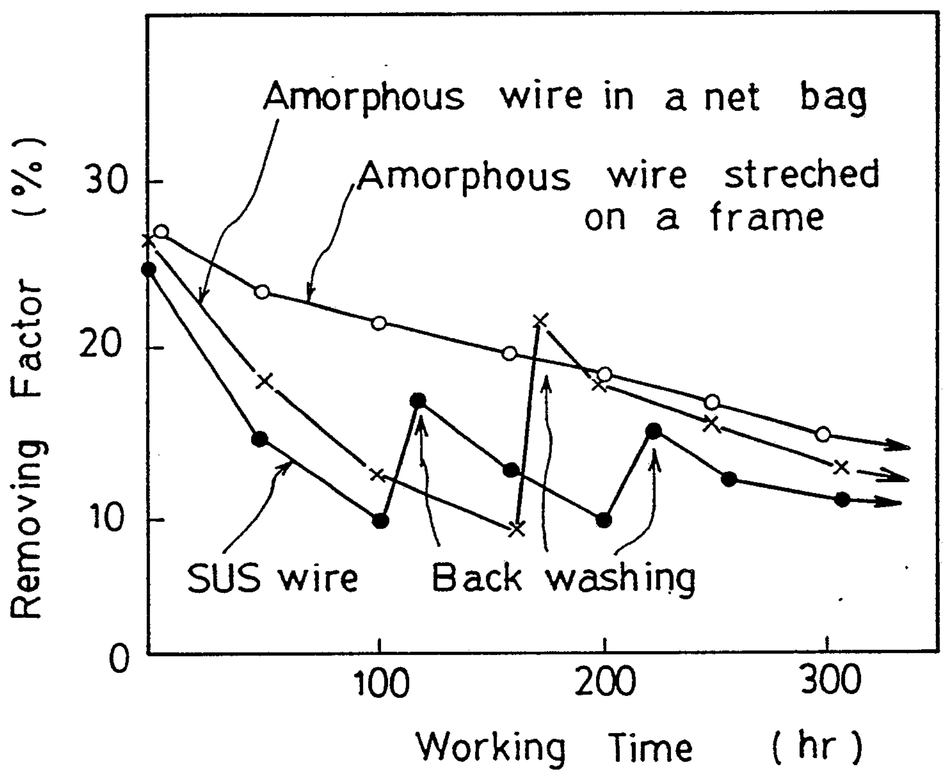

Amorphous wire in a net bag
Amorphous wire streched on a frame
Removing Factor (%)
30
20
10
0
100
200
300
SUS wire
Back washing
Working Time (hr)

FIG.16