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[57]	Abstract:	[Problem] To improve liquid dispersibility in a filler and improve the efficiency of processing a gas by providing a perforated plate on the filler and supplying a liquid onto the filler through openings in the perforated plate; moreover, to prevent a reduction in contact efficiency due to marine organisms infiltrating the device. [Solution] A prescribed filler (20) having substantially uniform flow channels in relation to a cross-section is provided inside a standing column (1), a gas to be treated is blown into the column from below the column, a perforated plate (5) having openings disposed in a substantially uniform manner is provided above the prescribed filler (20), a seawater distribution and supply means (3, 4) for distributively supplying seawater to an upper surface of the perforated plate is provided above the perforated plate (5), and contact is brought about between the gas blown up into the column and the descending liquid, so that the gas is treated.		

DESCRIPTION

FLUE GAS DESULFURIZATION APPARATUS AND FLUE GAS DESULFURIZATION METHOD

Technical Field

The present invention relates to a seawater flue gas desulfurization apparatus, and relates to a seawater flue gas desulfurization apparatus for performing an absorption treatment to disperse an object component into seawater by bringing a flue gas into contact with seawater selectively absorbing the object component in the gas in the apparatus.

Background Art

For example, a combustion flue gas discharged from the electric power generation facilities includes sulfur oxide, and therefore, it is necessary to remove this before the flue gas is discharged into the atmosphere. For removing sulfur oxide from a flue gas, a spray type absorbing tower, a perforated plate absorbing tower, a packed tower, and the like are well-known. Among these absorbers, a perforated plate absorbing tower installing "MORETANA" made by KUBOTA KASUI Corporation) as a perforated plate (MORETANA-method absorption tower) is an apparatus for removing sulfur oxide in a flue gas by bringing an absorbent into contact with the flue gas on the perforated plate, and is advantageous in that sulfur oxide removing performance is higher than that of the other absorbers.

As an absorbent used for the perforated plate absorbing tower, sodium hydroxide, magnesium hydroxide, calcium hydroxide, calcium carbonate, seawater, and the like are known. The process using the seawater out of these absorbents is advantageous in that no by-product is generated and the seawater having absorbed the sulfur dioxide can be discharged to sea.

Citation List

Patent Literature

Patent Literature 1: JP 2001-129352 A

Summary of Invention

Technical Problem

In a perforated plate absorbing tower, seawater, which flows downward, comes into counter-contact with a flue gas, which flows upward on a perforated plate. The seawater and the flue gas mix on the perforated plate, so that the sulfur oxide in the flue gas is removed.

It is extremely important to bring the flue gas into contact with the seawater efficiently on the perforated plate or on a surface of packing in order to improve the efficiency of the flue gas treatment (desulfurization efficiency).

However, the present inventors have found that, when the perforated plate absorbing tower is operated for long time, the operation efficiency decreases over the operation time. As the reason for this, the present inventors have found that aquatic organisms such as bivalvia (for example, mytilus galloprovincialis and perna viridis which are bivalvias in mytiloidea of mytiloida), sessile organisms (barnacle, and the like), and the like enter into the apparatus, and stay within the absorption tower.

A screen is provided in a seawater intake opening in order to prevent the invasion of the aquatic organisms and foreign materials from the seawater to the flue gas desulfurization system. However, the sizes of larvae and spats of some shells (mussel, Asian green mussel, and the like) are extremely small, e.g., 60 to 300 μm, so that they easily pass through the screen. They stick to and grow on the inner surface of the pipe for supplying the seawater to the absorption tower, and dead shells are unstuck from the surface and mixed into the inside of the absorption tower, resulting in internal clogging.

In reality, the present inventors were greatly surprised to observe even large sediments made of pieces of dead and unstuck shells in MORETANA in a flue gas desulfurization system after long operation time.

Therefore, a major object of the present invention is to improve the efficiency of an absorption treatment for a gas to be treated or the efficiency of a diffusion treatment from seawater by installing a perforated plate over packing and supplying a liquid onto the packing through each hole of the perforated plate and enhancing distribution property of the seawater for the packing.

Another object is to secure the high efficiency of a treatment for a gas to be treated by distribution-supplying seawater to the whole of a path through which the packing flows.

Still another object is, in order to solve a problem specific to a seawater flue gas desulfurization system, to prevent deterioration in efficiency of contacting, which would be caused by invasion of marine organisms into the system.

Solution to Problem

The inventors have found that it is important to bring a flue gas into contact with seawater efficiently on a perforated plate or on a surface of packing in order to improve efficiency of contact with the flue gas (desulfurization efficiency). Based on the above finding, the inventors have further attained new finding that, by the perforated plate installed over the packing onto which the seawater is supplied through each hole of the perforated plate in order to improve the efficiency of a flue gas treatment, a distribution property of the seawater for the packing is enhanced, and the efficiency of the contact with the flue gas is improved.

The present invention based on such findings is a flue gas desulfurization apparatus of a vertical tower comprising

structured packing which is provided with a communication path substantially uniform in a cross section, and from a site below which, a gas is blown into the tower so as to blow upward in the tower,

a perforated plate, which is provided with many holes disposed in a substantially uniform manner and which is installed over the structured packing, and

a seawater distribution-supplying unit, which is furnished above the perforated plate for distribution-supplying of the seawater onto an upper surface of the perforated plate,

so that gas liquid contact is performed between the gas, which is to be treated and which blows upward, and the seawater, which flows downward, for a treatment of the gas to be treated.

According to the present invention, the perforated plate is installed over the structured packing, and the seawater is supplied onto the structured packing through the holes of the perforated plate, so that the distribution property of the seawater for the packing is enhanced, and the contact efficiency with the gas can be enhanced.

On the other hand, the seawater distribution-supplying unit is provided with a supply pipe and many downward supply nozzles in communication therewith, and is configured to supply the seawater onto the perforated plate, and when each of at least some openings is align with the hole of the perforated plate in a vertical direction, a flow of the seawater can be formed, which passes through the hole of the perforated plate to the flow path of the structured packing, and from the view point of whole cross section of the tower, the flow of the seawater can be considered to be substantially uniform, and as a result, the liquid can be distribution-supplied to the entire flow path of the packing. Therefore, the gas-liquid contactor achieving high contact efficiency with the gas can be obtained.

On the other hand, the seawater distribution-supplying unit is provided with a supply pipe and many downward supply nozzles in communication therewith, and the supply nozzles may be arranged in a uniformly dispersed manner with a ratio of 2 pieces/m^2 to 4 pieces/m^2.

The diameter of the supply nozzle of the seawater distribution-supplying unit is preferably 50 to 150 mm, and more preferably, 65 to 125 mm, and the size of area in the cross section of a nozzle is preferably 0.002 to 0.018 m^2/pieces. Further, preferably 6 to 135 holes of the perforated plate and more preferably 13 to 65 holes of the perforated plate are located in a downwardly projected area with respect to a single supply nozzle.

The present invention further provides a flue gas desulfurization method comprising

loading in a vertical tower, structured packing, which is provided with a communication path substantially uniform in a cross section, and from a site below which, a gas is blown into the tower so as to blow upward in the tower,

installing over the structured packing, a perforated plate, which is provided with many holes disposed in a substantially uniform manner, and

furnishing above the perforated plate, a seawater distribution-supplying unit for distribution-supplying of the seawater onto an upper surface of the perforated plate,

so that gas liquid contact is performed between the gas, which is to be treated and which blows upward, and the seawater, which flows downward, for a treatment of the gas to be treated.

Also in the seawater-method flue gas desulfurization method, the seawater distribution-supplying unit supplying the seawater to the perforated plate is provided a supply pipe and many downward supply nozzles in communication therewith, and it is preferably that each of at least some openings is align with the hole of the perforated plate in a vertical direction.

The diameter of the hole of the perforated plate facing the supply nozzles is preferably 5 to 20 mmϕ, and more preferably 8 to 12 mmϕ, and the open ratio is preferably 25 to 60%, and more preferably 30 to 40%.

The number of holes of the perforated plate is preferably 3000 pieces/m^2 to 7800 pieces/m^2.

A flow velocity at a leading end of the supply nozzle is preferably 1.0 to 3.0 m/second, and more preferably, 1.5 to 2.5 m/second.

A superficial velocity of the gas blowing into the tower and blowing upward is preferably 2.0 m/second to 3.2 m/second, and a falling velocity of the seawater immediately above the structured packing is preferably equal to or more than 2.0 m/second.

At an intermediate portion in a height direction of the structured packing, it is preferred that many diagonal communication paths for the gas flowing in from a lower portion are provided, and a communication path is provided on at least an upper end portion to cause the diagonally ascending gas flowing through the diagonal communication path to ascend upward in the vertical direction.

A minimum passing diameter of the communication path in the height direction of the structured packing is preferably 10 to 30 mm.

What has been described above is overview of the present invention, and is technical matters based on the findings obtained from various kinds of experiments and operations over a long time.

As described above, the operation efficiency cannot be stabilized without preventing the reduction in the contact efficiency caused by the aquatic organisms entering into the apparatus. The present inventors have found that the sizes of larvae and spats of aquatic organisms are 60 to 300 μm, and it is impossible to prevent their invasion into the pipe for supplying the seawater to the absorption tower, and therefore, the present inventors have found a method of preventing the reduction in the operation efficiency from the perspective of allowing for such circumstances.

In this case, the present inventors focused on bivalvia such as mussel as an aquatic organism causing reduction of the operation efficiency in the apparatus. In this case, the bivalvia is, for example, mytilus galloprovincialis, perna viridis, and mytilus edulis which belong to mytiloidea of mytiloida. For example, the sizes of adults of the mytilus galloprovincialis and the perna viridis are about 30 to 50 mm. Therefore, the present inventors came up with an idea that these kinds of shells are allowed to pass through the supply pipe and supply nozzles of the seawater distribution-supplying unit distribution-supplying the seawater onto the upper surface of the perforated plate (i.e., the holes are configured to pass these kinds of shells), and they are mainly captured on the perforated plate, and the present inventors designed and operated the apparatus on the basis of such idea.

However, some of the shells such as larvae are small, or some of the shells are broken in the pipe to a smaller size. Therefore, materials having small diameters that have passed through the holes of the perforated plate are configured to drop through the communication path of the structured packing.

Further, the present inventors have found that the shells captured on the perforated plate are bubbled by the gas flowing upward from the lower portion in a liquid layer of the seawater formed on the perforated plate, and it is important to keep the shells and the like in a floating and moving state in which the shells and the like do not close or clog the holes of the perforated plate.

Advantageous Effects of Invention

According to the present invention, the perforated plate is provided above the structured packing, and the seawater is provided onto the structured packing through the holes of the perforated plate, so that the distribution property of the seawater for the structured packing is enhanced, and the contact efficiency with the gas can be improved.

In addition, the reduction of the contact efficiency caused by the aquatic organisms entering into the apparatus can be prevented, and it is possible to achieve not only improvement of the contact efficiency but also stable operation over long time.

Brief Description of Drawings

Fig. 1 is an example of installation of a flue gas desulfurization apparatus according to the present invention.

Fig. 2 is an elevation view illustrating an example of a flue gas desulfurization apparatus according to the present invention.

Fig. 3 is an elevation view illustrating overview of a gas-liquid contactor according to a comparative example.

Fig. 4 is an elevation view illustrating another example of overview of a flue gas desulfurization apparatus according to the present invention.

Fig. 5 is a partially enlarged view of Fig. 1.

Fig. 6 is an explanatory diagram illustrating an example of falling velocity distribution.

Figs. 7(a) and 7(b) are explanatory diagrams illustrating an example of the structured packing, in which Fig. 7(a) is a perspective view, and Fig. 7(b) is an assembly diagram illustrating a corrugated plate element thereof.

Fig. 8 is a longitudinal cross-sectional view illustrating an example of an apparatus.

Fig. 9 is an explanatory diagram illustrating an example of arrangement of seawater distribution pipes and nozzles shown in a top view.

Fig. 10 is a perspective view illustrating another example of seawater distribution-supplying unit.

Fig. 11 is an explanatory diagram in a top view illustrating an example of relationship of magnitudes between a supply nozzle and a hole of a perforated plate.

Fig. 12 is a perspective view illustrating another example of structured packing.

Fig. 13 is an explanatory diagram illustrating an example of falling velocity distribution in a case where the other example of structured packing is used.

Fig. 14 is an explanatory diagram illustrating an example of falling velocity distribution from a perforated plate to structured packing caused by change in the shape of a hole of the perforated plate.

Fig. 15 is an explanatory diagram illustrating an example of falling velocity distribution from a perforated plate to structured packing caused by change in the arrangement of the perforated plate.

Fig. 16 is an explanatory diagram illustrating an example of falling velocity distribution from a perforated plate to structured packing caused by change in the diameter of a hole of the perforated plate.

Fig. 17 is another example of installation according to the present invention.

Description of Embodiments

Preferred embodiments of a flue gas desulfurization apparatus according to the present invention will be hereinafter explained with reference to drawings. The explanation about the preferred embodiments below is merely an example of an essence, and is not intended to limit the application of the present invention or the purpose thereof.

Fig. 1 illustrates a flue gas treatment system using a flue gas desulfurization apparatus according to the present invention.

The flue gas desulfurization apparatus according to the present invention includes a flue gas fan 51 supplying combustion flue gas discharged from a thermal electric power generation plant and the like, a seawater flue gas desulfurization apparatus 50 treating the flue gas fed from the flue gas fan 51, a stack 52 discharging gas from which sulfur is removed by the seawater-method flue gas desulfurization apparatus 50, a seawater supplying pump 53 supplying the seawater to the seawater flue gas treatment apparatus 50, a screen 54 removing aquatic organisms in the seawater, and a seawater supplying pipe 55. The aquatic organisms are included in the seawater supplied from the seawater supplying pump 53. Among these aquatic organisms, small larvae and the like that could not be removed by the screen 54 stick to the seawater supplying pipe 55 and grow there.

The seawater in a lower portion of the seawater flue gas desulfurization apparatus 50 is mixed with seawater 57 separately supplied to a wastewater treatment system 56, and thereafter, the seawater is subjected to aeration processing with an aeration blower 58, and is discharged to the seawater in the ocean.

Fig. 2 is an elevation view (cross sectional view) of the first embodiment of the flue gas desulfurization apparatus according to the present invention, which is applied as the seawater flue gas treatment apparatus 50 of Fig. 1, for example.

As a basic constituent element of the flue gas desulfurization apparatus, a feed port 2 is provided on a side surface of a lower portion of the gas-liquid contactor 1 to supply a flue gas (for example, a combustion flue gas fed from a waste-heat boiler in an electric power generation system) G. On the upper surface of the gas-liquid contactor 1, an exhaust port 6 is provided to exhaust treated flue gas TG that has been treated in the gas-liquid contactor 1.

A supply pipe 3, which supplies fresh seawater SW as an absorbent into the gas-liquid contactor 1, and many nozzles 4, which are connected to the supply pipe 3 and configured to spray the received fresh seawater SW to the lower side of the gas-liquid contactor 1, are provided on the upper portion of the gas-liquid contactor 1.

In the present embodiment, a typical example of "fresh seawater" SW is seawater retrieved from the ocean, and is distinguished from the seawater including sulfur oxide having been subjected to an absorption treatment performed on the perforated plate 5 in the gas-liquid contactor 1 explained later. The fresh seawater may be other than those directly obtained from the ocean explained above. Used cooling water discharged from a condenser of a boiler system and brine discharged from a seawater desalination system can also be used.

In this first embodiment, the supply pipe 3 and the nozzle 4 constitute seawater distribution-supplying unit according to the present invention. The shape of the opening of the supply nozzle 4 is not limited to a circular shape, a rectangular shape, and a polygonal shape, but a circular shape is preferable. It should be noted that the diameter of the supply nozzle 4 is preferably 50 to 150 mm, and more preferably, 65 to 125 mm. When the shape is a rectangular shape and a polygonal shape, the diameter of the supply nozzle 4 corresponds to the maximum length of the opening. The fresh seawater SW may include solid materials such as shells and seaweeds, and this may cause clogging in the nozzle. Therefore, when the diameter of the nozzle 4 is equal to or more than 50 mm, the shells and the like are allowed to pass, and the seawater can be sprayed while the clogging of the nozzle can be prevented. The diameter of the supply pipe 3 is also preferably equal to or more than 50 mm.

Further, a perforated plate (for example MORETANA) 5 of which open ratio is preferably 25 to 60% and more preferably 30 to 40% is provided below the supply pipe 3 and the nozzles 4 of the gas-liquid contactor 1.

The perforated plate is provided with holes 5a with a ratio of 3000 pieces/m^2 to 7800 pieces/m^2.

The shape of the hole 5a of the perforated plate is not limited to a circular shape, a rectangular shape, and a polygonal shape, but a circular shape is preferable. The diameter of the hole of the perforated plate is preferably 5 to 20 mm, and more preferably 8 to 12 mm. When the shape is a rectangular shape and a polygonal shape, the diameter of the opening corresponds to the maximum length of the hole. When the diameter is 5 to 20 mm, contaminants such as shells included in the fresh seawater sprayed from the seawater distribution-supplying unit easily drop from holes of the perforated plate onto the structured packing, and on the other hand, the contaminants can be prevented from accumulating on the perforated plate 5 for long time. The diameter of the hole of the perforated plate is set to be smaller than that of the opening of the nozzle of the seawater distribution-supplying unit as explained above, so that the contaminants (in particular, shells and the like) included in the seawater can be captured on the perforated plate. The captured contaminants can be removed when the operation is stopped.

Many of the flue gas desulfurization apparatuses using the seawater in a conventional example simply have such a structure provided with multiple perforated plates (MORETANA) 5 in the height direction, but are not provided with any structured packing.

On the other hand, a gas-liquid contactor is known, which is provided with structured packing and spraying seawater from a site above the structured packing.

In the present invention, both are used together, and the structured packing 20 is provided below the perforated plate 5. Reference numeral 21 denotes a perforated support member supporting the bottom surface of the structured packing 20. The structured packing is not limited to a single stage. The structured packing preferably has multiple stages in order to improve the contact efficiency.

The flue gas G supplied from the feed port 2 disposed on a side surface in a lower portion of the gas-liquid contactor 1 moves upward in the gas-liquid contactor 1, and moves through the flow path of the structured packing 20 and the holes of the perforated plate 5 in this order.

On the other hand, the fresh seawater SW is supplied through the supply pipe 3 to the supply nozzle 4. It should be noted that the supply pipe 3 is also connected to a pipe for supplying a portion of the seawater having absorbed sulfur oxide accumulated in a lower portion of the gas-liquid contactor 1, so that the seawater can be recycled and used in accordance with operation. The fresh seawater SW sprayed to the lower side from the supply nozzle 4 disposed in the upper portion of the gas-liquid contactor 1 comes into counter-contact with the flue gas G on the perforated plate 5 disposed in the middle portion in the gas-liquid contactor 1, at the upper end of the structured packing 20, and in the flow path. With this counter-contact, the sulfur oxide included in the flue gas is absorbed by the fresh seawater SW, and removed from the flue gas. The sulfur oxide having absorbed the sulfur component in the flue gas is fed from the discharge port provided in the lower portion of the gas-liquid contactor 1 via the flow path to the wastewater treatment system.

At this occasion, a ratio (L/G) between the flow rate G ($kg/m^2 \cdot hr$) of the flue gas G and the flow rate L ($kg/m^2 \cdot hr$) of the fresh seawater SW is 3 or more, and preferably, 4 to 15.

The treated flue gas TG from which the sulfur oxide has been removed is discharged from the exhaust port 6 disposed at the upper portion of the gas-liquid contactor 1. The seawater having absorbed the sulfur oxide descends to the lower side in the gas-liquid contactor 1.

In the present invention, in a vertical tower, structured packing 20 is loaded, which is provided with a communication path substantially uniform in a cross section, and from a site below which, a gas to be treated (such as a flue gas G) is blown into the tower, a perforated plate 5, which is provided with holes disposed in a substantially uniform manner and which is installed over the structured packing 20, and a seawater distribution-supplying units 3, 4, which are furnished above the perforated plate 5 for distribution-supplying of the liquid onto the perforated plate 5, so that gas liquid contact is performed between the gas, which is to be treated and which blows upward in the tower, and the seawater, which flows downward, for a treatment of the gas to be treated.

According to the above configuration, while the seawater supplied from the seawater distribution-supplying unit 3, 4 disperses in the surface direction on the perforated plate 5, the seawater passes through the holes 5a, 5a, ... to the lower side of the flow paths 20a, 20a ... of the structured packing 20. Therefore, as compared with a case where the perforated plate 5 is not provided and the seawater directly flows downward from the seawater distribution-supplying unit 3, 4 to the flow paths 20a, 20a ... of the structured packing 20, the distribution property of the seawater is enhanced, and the gas-liquid contact efficiency is improved.

According to the present invention, in addition to the gas-liquid contact on the perforated plate 5, the seawater supplied from the seawater distribution-supplying unit 3, 4 flows downward to the flow paths 20a, 20a ... of the structured packing 20 for achieving the gas-liquid contact.

Therefore, since the gas-liquid contact is also performed while it passes through the flow paths 20a, 20a ... having a long channel in the height direction of the structured packing 20, gas-liquid contact can be performed for long time, the gas-liquid contact efficiency is enhanced also from this point of view.

Meanwhile, when the seawater supplied from the seawater distribution-supplying unit 3, 4 flows downward to the flow paths 20a, 20a ... of the structured packing 20 to achieve the gas-liquid contact, there may be a flow path 20a through which no seawater passes unless, for example, many nozzles 4 are provided.

On the other hand, when many nozzles 4 are provided, the cost of the seawater distribution-supplying unit 3, 4 increases. However, according to the present invention, when the seawater is supplied from the supply nozzles 4, the supplying positions of the seawater are arranged in advance in a dispersed manner in the surface direction on the perforated plate 5, and accordingly, the seawater can be distribution-supplied to the structured packing 20, and the seawater can pass through the flow paths 20a, 20a ... thereof smoothly to the lower side. As a result, even when the number of nozzles 4 is decreased, a sufficient distribution property of seawater can be ensured.

In the example of Fig. 2, the configuration of the present invention is provided, namely, the structured packing, the perforated plate having the holes, and the seawater distribution-supplying unit supplying the seawater are provided for the gas, which is to be treated and which blows upward. Alternatively, this configuration may be provided in multiple stages with an interval in the height direction.

The example of Fig. 4 shows a case where the structured packing and the seawater distribution-supplying unit supplying the seawater are provided, and further, the structured packing, the perforated plate having the holes, and the seawater distribution-supplying unit supplying the seawater are provided thereabove. In the example of Fig. 4, with the seawater distribution-supplying unit supplying the seawater and the perforated plate in the upper stage, the seawater flows downward uniformly onto the structured packing at the upper stage, and therefore, it is not necessary to provide any perforated plate having holes at the lower stage, and this contributes to also to prevent pressure loss.

Subsequently, a comparative experiment of gas-liquid contact efficiency was conducted under the following experimental condition.

Experiment apparatus: absorption tower size of 1500 mm by 1500 mm, and height of 3000 mm

Packing: resin-made structured packing (300 mm height/module)

Filling height: one stage

Supply gas flow rate: 24,000 m^3/H

Supply gas component: air

Supplied liquid flow rate: 144 m^3/H

<Experiment 1>: no perforated plate provided over the structured packing (configuration of Fig. 3)

<Experiment 2>: perforated plate provided over the structured packing (configuration of Fig. 2)

On the basis of this experiment result, the number of nozzles required to obtain predetermined gas-liquid contact efficiency was calculated.

According to the calculation result, the present inventors have found that, in the case of the experiment 1, the nozzles need to be arranged at a rate of about 20 pieces/m^2, but in the case of the experiment 2, the nozzles arranged at a rate of about 4 pieces/m^2 are sufficient.

Subsequently, other embodiments of the absorption tower will be shown in Figs. 8 and 9. In this example, multiple seawater distribution-supplying units 3, 4 may be provided in the height direction. Fig. 9 is a top view illustrating the seawater distribution-supplying unit. The seawater distribution-supplying unit according to this structure is provided with a supply pipe 3 for carrying seawater supplied from the outside as shown in Fig. 8 and many downward supply nozzles 4 in communication therewith. The supply pipe 3 is in communication with the supplied liquid supply nozzle X provided on a side surface in a lower portion of the main body of the absorption tower, and extends horizontally to the center in the horizontal cross sectional plane of the main body of the absorption tower, and extends upward from the vicinity of the center. After the supply pipe 3 extends to the upper side of the structured packing filled in the absorption tower, the supply pipe 3 branches off in the horizontal direction, and the each of the branched pipes is provided with downward supply nozzles 4.

The supply nozzles are preferably has such structure that the supply nozzles are distribution-arranged with a ratio of one piece/m^2 to 100 pieces/m^2, and more preferably, the supply nozzles are distribution-arranged with a ratio of two pieces/m^2 to 6 pieces/m^2 in the supply pipe. When too many supply nozzles are provided, the weight of the seawater distribution-supplying unit increases. In particular, since the seawater distribution-supplying unit is disposed in the upper portion of the absorption tower, the center of gravity of the entire absorption tower would become higher, and accordingly, this would increase the size of the entire apparatus, e.g., a large foundation would be required.

Another example of seawater distribution-supplying unit is shown in Fig. 10 which includes an upper opening pipe passage and effluent weir openings formed on a side wall thereof, and the openings may be distribution-arranged with a ratio of two pieces/m^2 to 50 pieces/m^2.

The flue gas G fed from the feed port 2 disposed on a side surface in a lower portion of the gas-liquid contactor 1 moves upward in the gas-liquid contactor 1, and moves through the openings of the perforated support member 21 (see Fig. 8), the flow path of the structured packing 20 and the holes of perforated plate 5 in this order.

On the other hand, the fresh seawater SW sprayed downward from the supply nozzles 4 provided at the upper portion of the gas-liquid contactor 1 comes into counter-contact with the flue gas G on the perforated plate 5 disposed in the middle portion in the gas-liquid contactor 1, at the upper end of the structured packing 20, and in the flow path. With this counter-contact, the sulfur oxide included in the flue gas is absorbed into the fresh seawater SW, and removed from the flue gas. As shown in Fig. 8, preferably, an eliminator 22 is provided above the nozzles 4 to remove mist in the treated flue gas G.

In a case of a seawater flue gas desulfurization apparatus, a superficial velocity of the gas, which is to be treated and which blows upward in the tower 1 is preferably 2.0 m/second to 3.2 m/second due to the relationship between the required quantity of the treated gas and the size of the apparatus.

Because of this factor, a new problem is raised. More specifically, at first, the present inventors thought that the seawater supplied from the seawater distribution-supplying unit 3, 4 flows downward to be finally dispersed on the perforated plate 5, and therefore, the direction of the nozzles may be set upward.

However, the present inventors have found that, when even a small drift occurs in the gas in the transverse plane above the perforated plate because the superficial velocity of the ascending gas is fast, the seawater is affected by the drift of the gas, and the seawater flows downward with a deviation in the transverse plane.

Therefore, the seawater is preferably supplied such that the supply nozzles are installed downward. When the present invention is applied to the seawater flue gas desulfurization apparatus, the falling velocity of the seawater immediately above the structured packing 20 is preferably equal to or more than 2.0 m/second, and more preferably, equal to or more than 2.5 m/second.

The present inventors further studied various aspects. As a result, as shown in Fig. 6, the present inventors found it is preferable that (the center of) much of liquid flow, which is supplied from the seawater distribution-supplying unit 4 and which flows downward onto the upper surface of the perforated plate 5, is substantially align with the center of the hole 5a of the perforated plate 5 in the vertical direction.

The seawater supplied from the seawater distribution supply nozzle 4 flows down so as to be dispersed in the surface direction of the perforated plate 5 while bouncing on the perforated plate 5. In normal cases, the ratio (L/G) between the flow rate G ($kg/m^2 \cdot hr$) of the flue gas G and the flow rate L ($kg/m^2 \cdot hr$) of the fresh seawater SW is 4 to 15, and therefore, a liquid layer is formed on the seawater perforated plate 5. The depth of the liquid layer at this occasion would be 5 mm to 200 mm when the flue gas G is not supplied. The liquid layer is greatly fluidized according to the increase of the flue gas. Further, while the contaminants such as shells and the like are fluidized, the clogging of the holes 5a of the perforated plate 5 can be prevented.

Therefore, when the position of the liquid flow dropped from the seawater distribution supply nozzle 4 onto the upper surface of the perforated plate 5 is substantially align with the position of the hole 5a of the perforated plate 5 in the vertical direction, the kinetic energy of the liquid flowing downward becomes clearly stronger than that of the gas flowing upward.

As a result, like the falling velocity distribution as shown in Fig. 6, there is a peak at the position substantially being align with the center of the hole 5a of the perforated plate 5 in the vertical direction.

When there are many peaks in a transverse plane in falling velocity distribution, the kinetic energy of the liquid flowing downward is greatly stronger than that of the gas flow upward at the peak positions. Therefore, this causes a situation where as if the liquid starts to flow downward from the hole 5a, and the liquid reliably flows into the flow path 20a of the structured packing 20. Further, the liquid flows downward from the position of each hole 5a of the perforated plate 5, and in addition, the liquid flows downward so as to be dispersed, and therefore, the liquid flows downward in a dispersed manner through the flow path 20a of the structured packing 20, which is extremely preferable.

The minimum passing diameter of the communication path in the height direction of the structured packing 20 is preferably 10 to 30 mm. It is preferable that some of the contaminants floating above the perforated plate 5 drop down through the holes 5a, pass through the structured packing 20, and flow downward from the lower end. For this reason, the minimum passing diameter of the diagonal communication path 20A, the communication path 20B, and the communication path 20C of the structured packing 20 explained below is preferably 10 to 30 mm. The minimum passing diameter of 10 to 30 mm is deeply related to the diameter of the hole of the perforated plate of 5 to 20 mmϕ, but most of the contaminants are in the floating and holding state above the perforated plate 5 and therefore the diameter is set such that contaminants, which would have passed through the holes of the perforated plate, flow downward smoothly.

The seawater distribution-supplying unit includes the supply pipe 3 and many downward supply nozzles 4 in communication therewith, and for example, the supply nozzles are distribution-arranged with a rate of 2 pieces/m^2 to 50 pieces/m^2. The diameter of the opening of the supply nozzle of the seawater distribution-supplying unit is preferably 50 mm to 150 mm, and more preferably 65 mm to 125 mm.

Fig. 11 shows an example of the diameter of the opening of the supply nozzle 4 and the hole 5a of the perforated plate 5, and positional relationship of the hole 5a of the perforated plate 5 on a downwardly projected area with respect to a single opening of supply nozzle 4.

Such a positional relationship is preferable that 6 to 135 holes of the perforated plate are located in the downwardly projected area with respect to the single supply nozzle 4, and more particularly, such a positional relationship is preferable that 13 to 63 holes of the perforated plate are located in the downwardly projected area with respect to the single supply nozzle 4. In Fig. 11, for example, about 13 openings are located. Multiple holes of the perforated plate are located in the downwardly projected area with respect to the single supply nozzle 4, and therefore, even if clogging is occurred in one of the holes 5a of the perforated plate 5 installed below the supply nozzle 4, at least one of the remaining holes 5a indicates the peak of the falling velocity, and accordingly, the seawater can be reliably supplied to the structured packing 20.

On the other hand, as shown in Fig. 10, the seawater distribution-supplying unit may include an upper opening pipe passage 40 and effluent weir openings 40B formed on a side wall 40A thereof, and the openings 40B may be distribution-arranged with a rate of 2 pieces/m^2 to 50 pieces/m^2.

The structured packing according to the present invention may be made of, e.g., the structured packing 20 as shown in

Fig. 7, and this will be explained below. The structured packing 20 as shown in Fig. 7 is such that many corrugated plates A and many corrugated plates B are stacked and arranged alternately so that the ridgelines of waves are different from each other between the adjacent plates by 90 degrees, whereby many flow paths of which directions are different by 90 degrees are formed. The crossing angle may be other angles (for example, 45 or 60 degrees). Alternatively, structured packing 20 in which flow path is not inclined may also be used.

Such an appropriate volume size is such that the structured packing 20 is spread to fit within the tower 1, and this may be performed in a single stage or multiple stages as necessary. When the structured packing 20 is spread to fit within the tower 1, the directionality may be changed for structured packing 20 so that the flow path directions are arranged more randomly.

On the other hand, as shown in Figs. 12 and 13, at an intermediate portion in a height direction of the structured packing 20, many diagonal communication paths 20A for the gas flowing in from a lower portion may be provided, and a communication path 20B may be provided on at least an upper end portion to cause the diagonally ascending gas flowing through the diagonal communication path 20A to ascend upward in the vertical direction. At a lower end portion, a communication path 20C may also be provided to guide the gas in the vertical direction.

In such mode, as described above, the gas flowing in ascends vertically in a regular manner, and therefore, the deviation of the descending seawater can also be prevented. Fig. 13 shows an example of falling velocity distribution in a case where the present other example of structured packing is used.

The structured packing is not limited to the examples shown above, and various kinds of structured packing available in the market or publicly known can be used.

As a relationship between the holes 5a of the perforated plate and the flow-down tube portion of the seawater of the supply nozzle 4, techniques such as making an hole 5a which enlarges to the lower side as shown in Fig. 14, decreasing the number of holes 5a immediately below the supply nozzle 4 as shown in Fig. 15, and decreasing the diameter of the hole 5a immediately below the supply nozzle 4 of Fig. 16 may be employed as necessary in order to define the mode of flow down of the flow-down liquid onto the structured packing.

Fig. 17 shows a desulfurization apparatus for a ship which is another example of installation of a flue gas desulfurization gas-liquid contactor. In this example, flue gas discharged from a ship engine 61 provided in a ship 60 is treated using a flue gas desulfurization tower 50A according to the present invention. The apparatus includes a ship engine (diesel engine tower) for driving a ship 1, a seawater flue gas desulfurization tower 50A for treating the flue gas of the ship engine 61, a water suction pump 62 for supplying seawater to the seawater flue gas desulfurization tower 50A, a screen 63 for removing aquatic organisms in the seawater, a flue gas fan 68 for discharging the flue gas treated by the flue gas desulfurization tower 50A into the atmosphere, a stack 64, a seawater storage tank 65 for storing seawater having absorbed sulfur oxide in the seawater flue gas desulfurization tower 50A, a wastewater treatment apparatus 66 for removing contaminants therefrom, and a discharge pipe passage 67.

The seawater flue gas treatment tower has the same structure as the first embodiment. The combustion flue gas of the diesel engine is brought into contact with the seawater, so that the sulfur oxide in the combustion flue gas is absorbed into the seawater. The seawater having absorbed the sulfur oxide is discharged to the ocean through the discharge pipe passage 67.

The seawater-method flue gas desulfurization apparatus disclosed in the present invention can be applied to desulfurization treatment for absorbing the sulfur component in the flue gas but also publicly known absorption process such as a hydrochloric acid recovery system where hydrogen chloride is absorbed into water, and a system for absorbing nitrogen oxide in the flue gas into seawater for removing the same. In addition, the seawater-method flue gas desulfurization apparatus disclosed in the present invention can be applied to a desorption process for desorbing organic substances in the wastewater into a gas using air and steam.

Reference Signs List

1	gas-liquid contactor
2	feed port
3	supply pipe
4	nozzle
5	perforated plate (MORETANA)
5a	hole
6	exhaust port
20	structured packing
G	flue gas
TG	treated flue gas
SW	fresh seawater

CLAIMS

1. A flue gas desulfurization method comprising:

loading in a vertical tower, structured packing, which is provided with a communication path substantially uniform in a cross section, and from a site below which, a gas to be treated is blown into the tower to cause the gas to move upward in the tower;

installing over the structured packing, a perforated plate, which is provided with many holes disposed in a substantially uniform manner; and furnishing above the perforated plate, a seawater distribution-supplying unit for distribution-supplying of the seawater onto an upper surface of the perforated plate,

wherein a diameter of the hole of the perforated plate is 5 to 20 mm, and an open ratio is 25 to 60%,

the seawater distribution-supplying unit includes a supply pipe and a plurality of downward supply nozzles in communication therewith, a diameter of the supply nozzle is 50 to 150 mm,

a superficial velocity of the gas to be treated is 2.0 m/second to 3.2 m/second,

a ratio (L/G) between the flow rate G ($kg/m^2 \cdot hr$) of the gas to be treated G and the flow rate L ($kg/m^2 \cdot hr$) of the seawater is 4 to 15,

a liquid layer is formed on the perforated plate by the seawater, and contact is performed between the gas to be treated and the seawater, which flows downward, and

in a flow path of the structured packing, contact is performed between the gas to be treated which flows upward and the seawater, which flows downward for a treatment of the gas to be treated.

2. The flue gas desulfurization method according to claim 1, wherein a number of the holes of the perforated plate is 3000 pieces/m^2 to 7800 pieces/m^2.

3. The flue gas desulfurization method according to claim 1, wherein the seawater distribution-supplying unit has a plurality of openings supplying the seawater to the perforated plate, and a center of each of at least some openings is align with the hole of the perforated plate in a vertical direction.

4. The flue gas desulfurization method according to claim 1, wherein the seawater distribution-supplying unit includes a supply pipe and a large number of downward supply nozzles in communication therewith, and the supply nozzles are distribution-arranged with a rate of 2 pieces/m^2 to 50 pieces/m^2.

5. The flue gas desulfurization method according to claim 1, wherein the seawater distribution-supplying unit includes a supply pipe and a large number of downward supply nozzles in communication therewith, a diameter of the supply nozzle is 50 to 150 mm, and 6 to 135 holes of the perforated plate are located in a downwardly projected area with respect to a single supply nozzle, and a flow velocity at a leading end of the supply nozzle is 2.0 to 3.0 m/second.

6. The flue gas desulfurization method according to claim 1, wherein at an intermediate portion in a height direction of the structured packing, a large number of diagonal communication paths for the gas flowing in from a lower portion are provided, and a communication path is provided on at least an upper end portion to cause the diagonally ascending gas flowing through the diagonal communication path to ascend upward in the vertical direction.

7. The flue gas desulfurization method according to claim 1, wherein a minimum passing diameter of the communication path in the height direction of the structured packing is 10 to 30 mm.

8. A flue gas desulfurization apparatus of a vertical tower configured to carry out the method according to any one of claims 1-7 comprising:

structured packing which is provided with a communication path substantially uniform in a cross section, and from a site below which, a gas to be treated is blown into the tower to cause the gas to move upward in the tower;

a perforated plate, which is provided with many holes disposed in a substantially uniform manner, and which is installed over the structured packing; and a seawater distribution-supplying unit, which is furnished above the perforated plate for distribution-supplying of the seawater onto an upper surface of the perforated plate,

wherein a diameter of the hole of the perforated plate is 5 to 20 mm, and an open ratio is 25 to 60%, the seawater distribution-supplying unit includes a supply pipe and a large number of downward supply nozzles in communication therewith, a diameter of the supply nozzle is 50 to 150 mm,

a liquid layer is formed on the perforated plate by the seawater, and contact is performed between the gas to be treated and the seawater, which flows downward, and

in a flow path of the structured packing, contact is performed between the gas to be treated which flows upward and the seawater, which flows downward for a treatment of the gas to be treated.

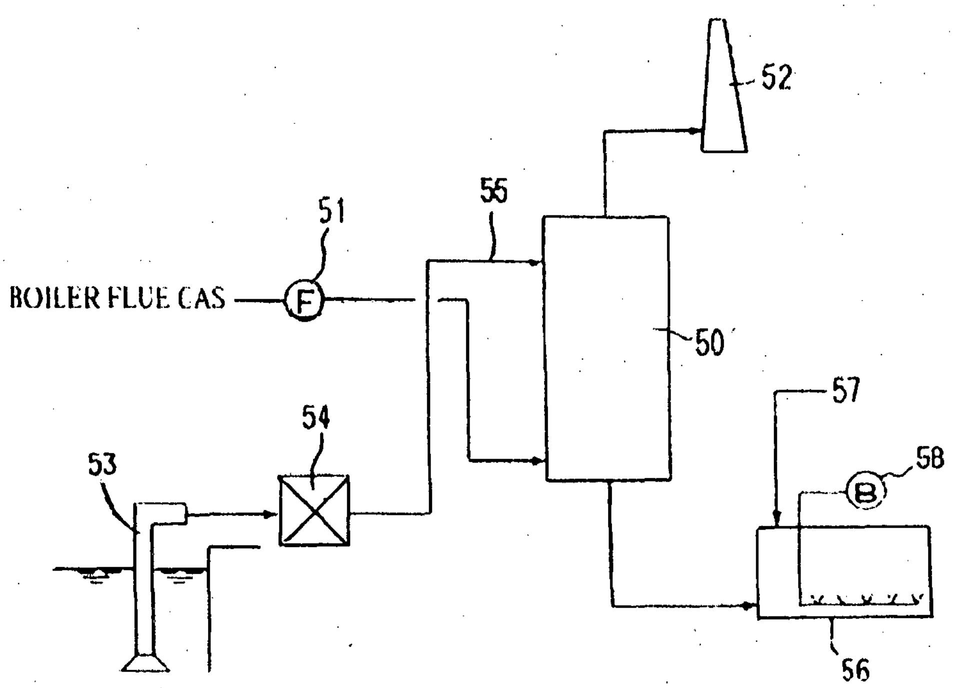

Figure 1

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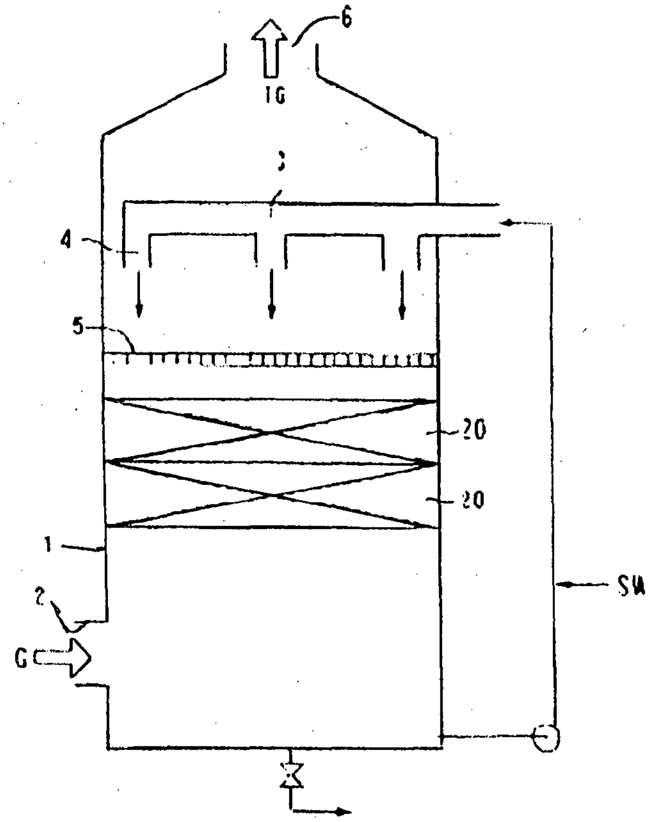

Figure 2

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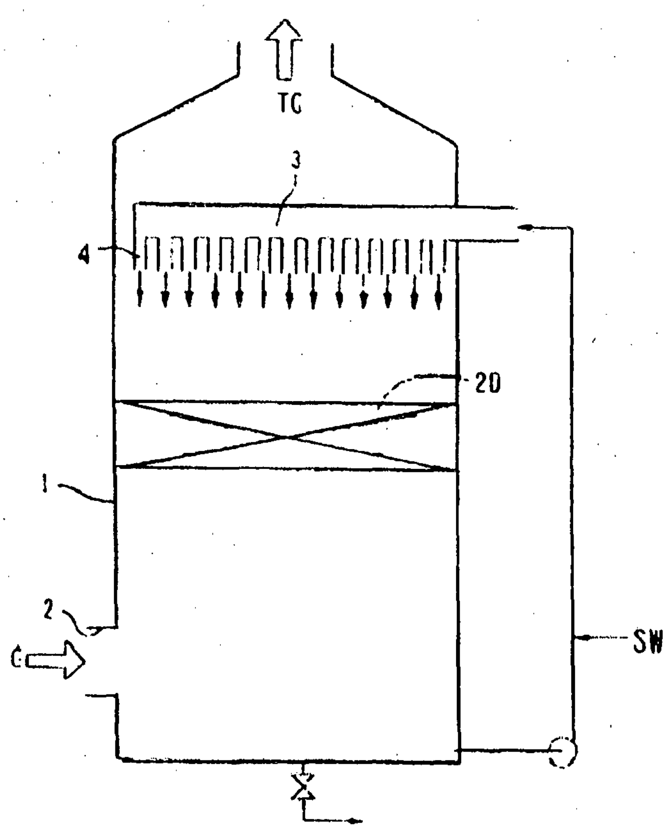

Figure 3

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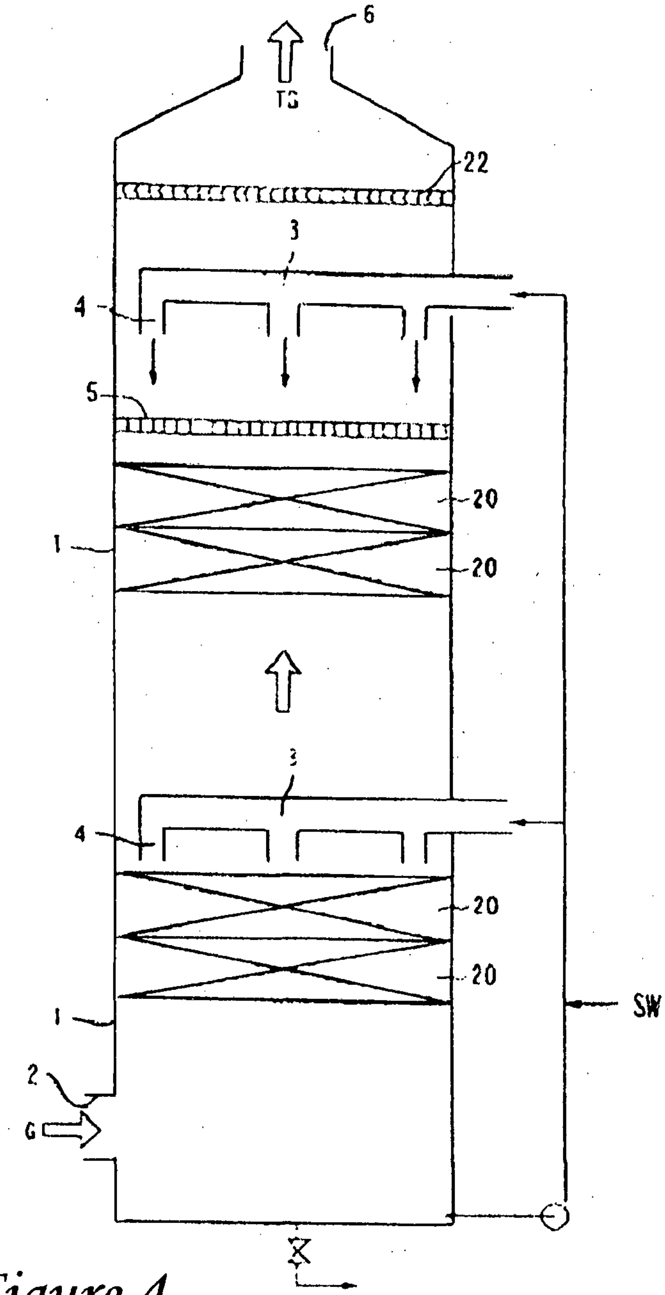

Figure 4

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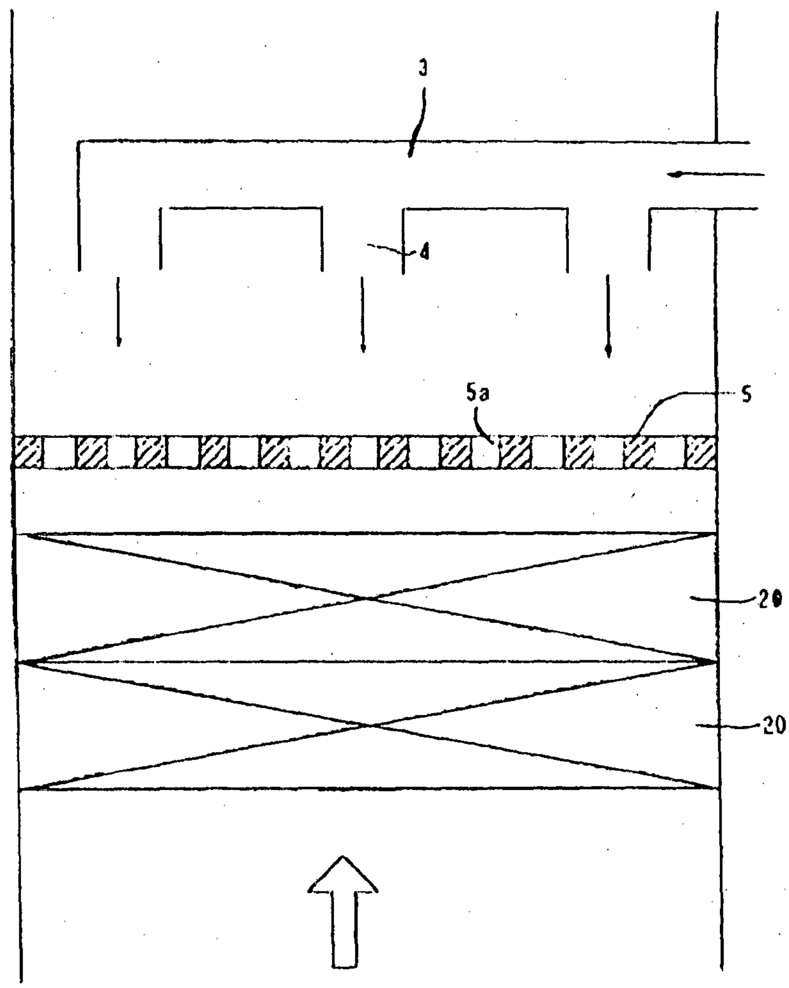

Figure 5

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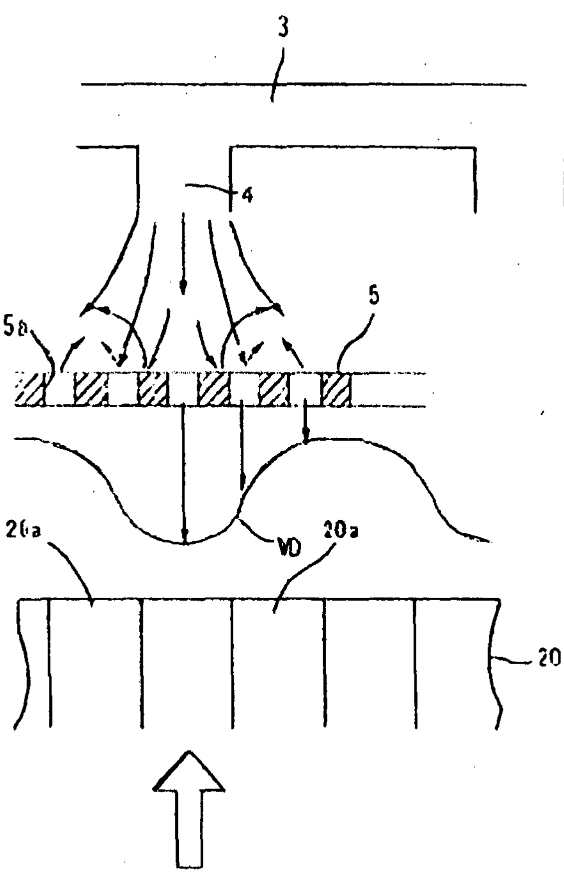

Figure 6

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Figure 7A

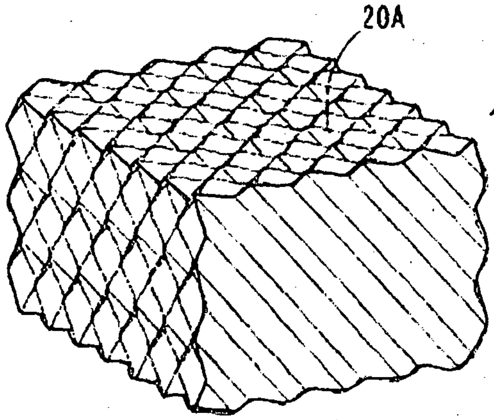
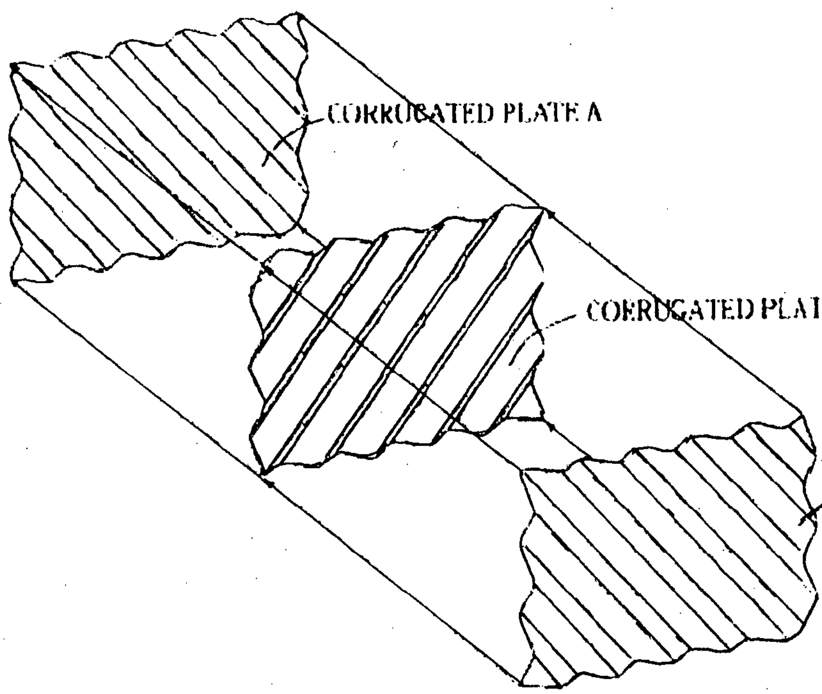


Figure 7B



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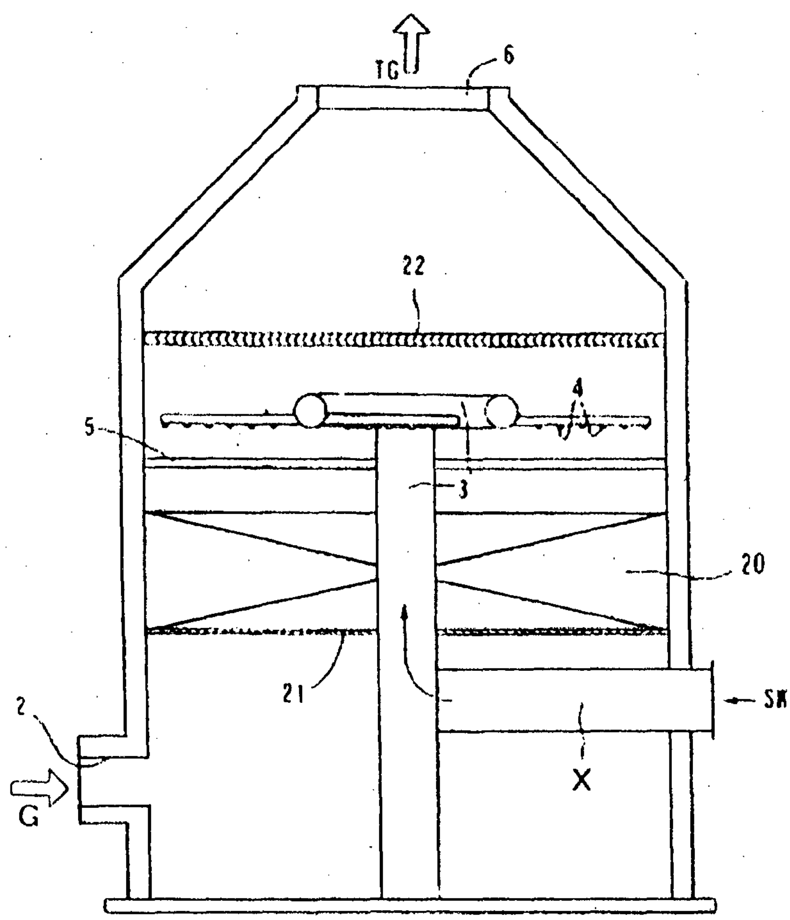

Figure 8

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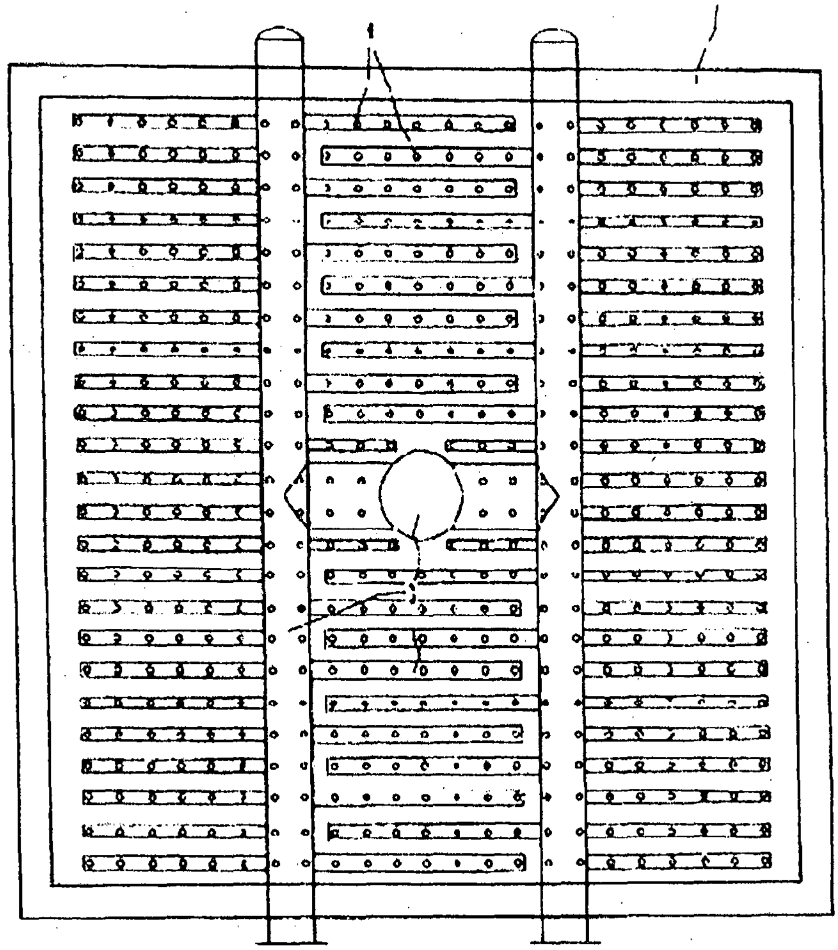

Figure 9

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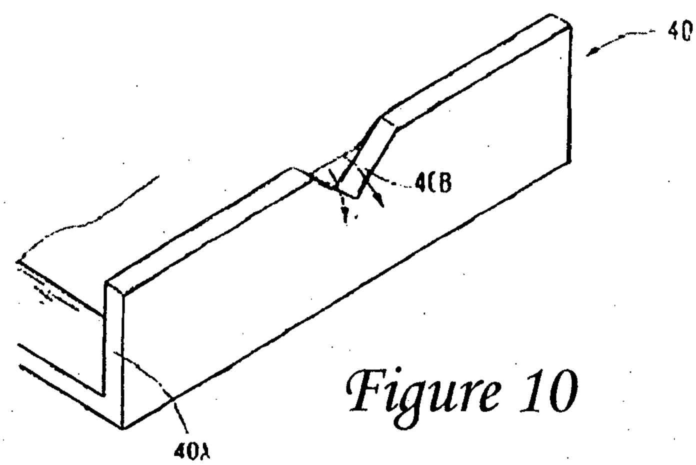

Figure 10

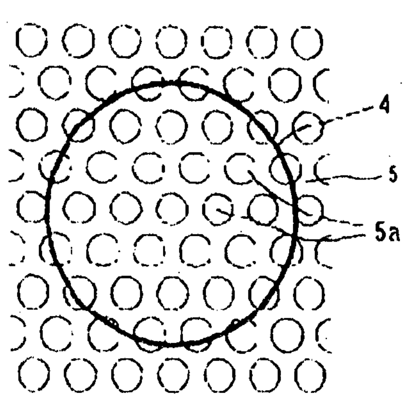

Figure 11

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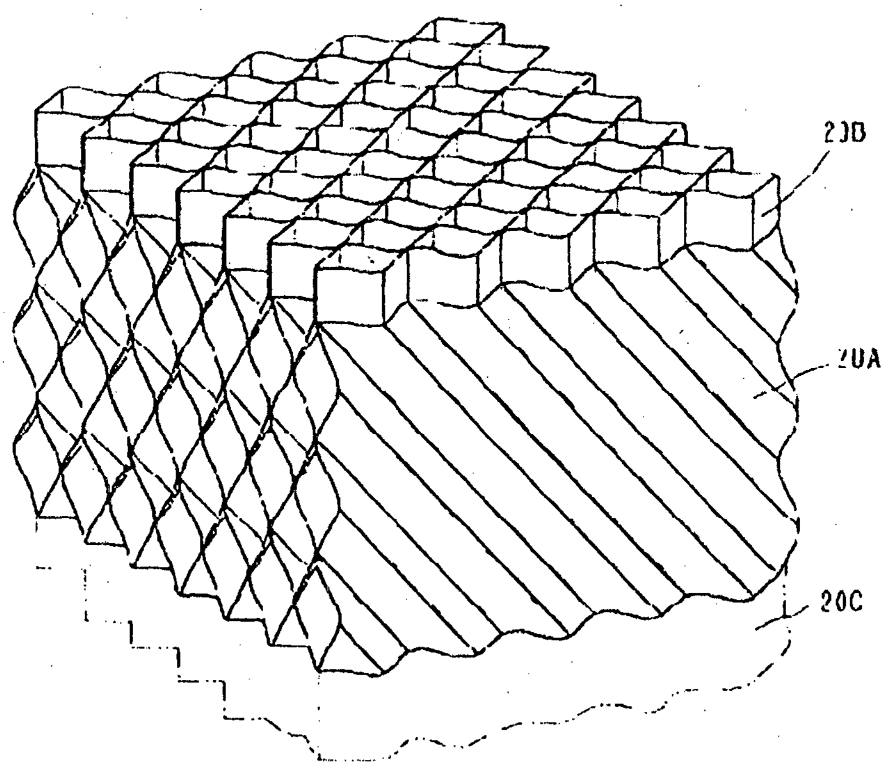

Figure 12

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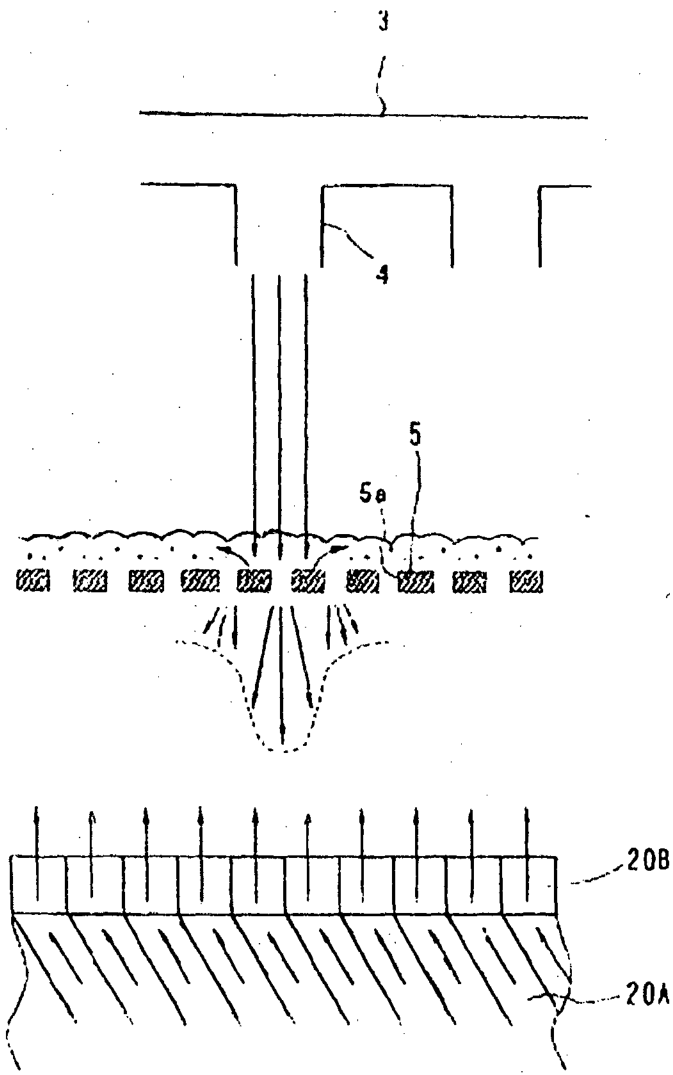

Figure 13

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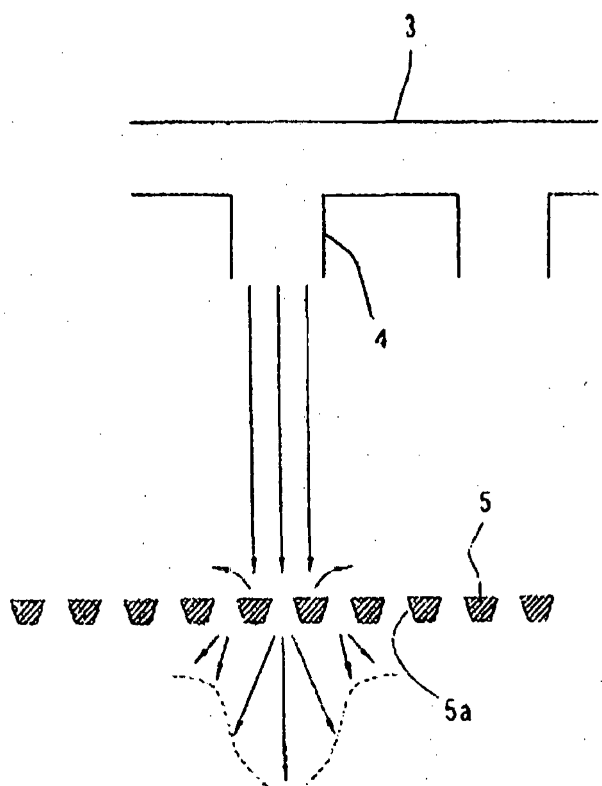

Figure 14

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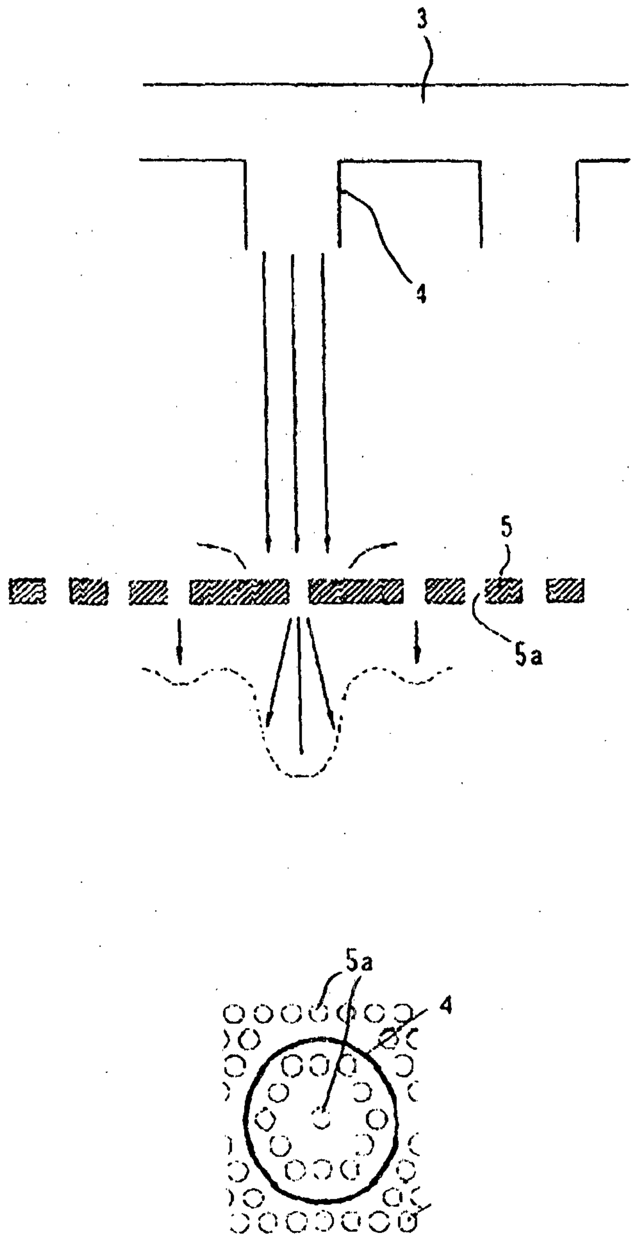

Figure 15

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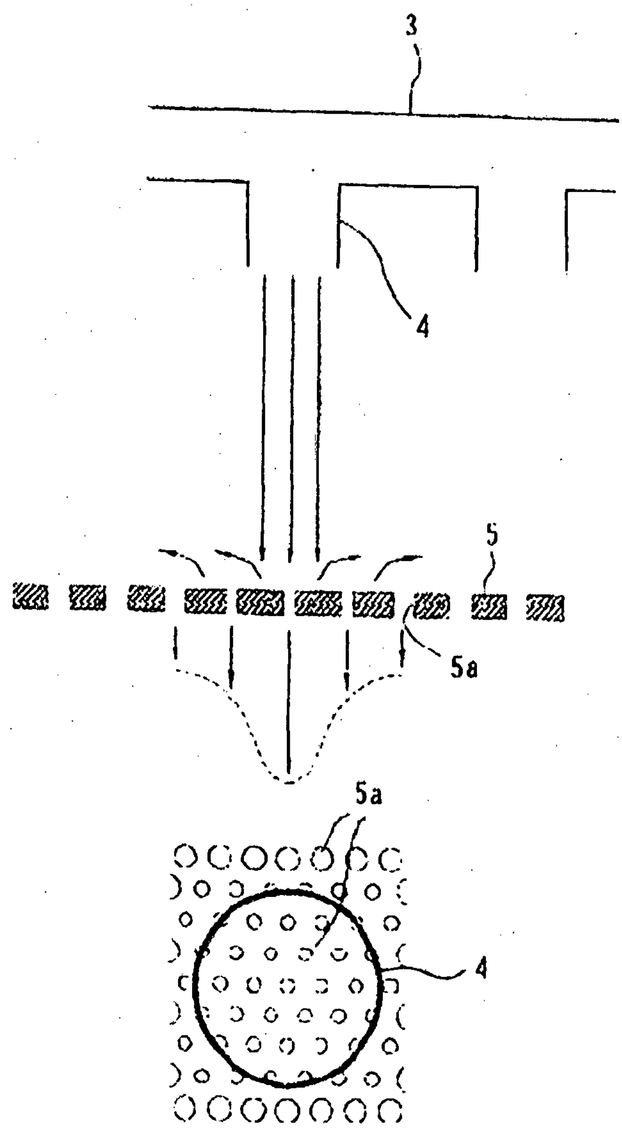

Figure 16

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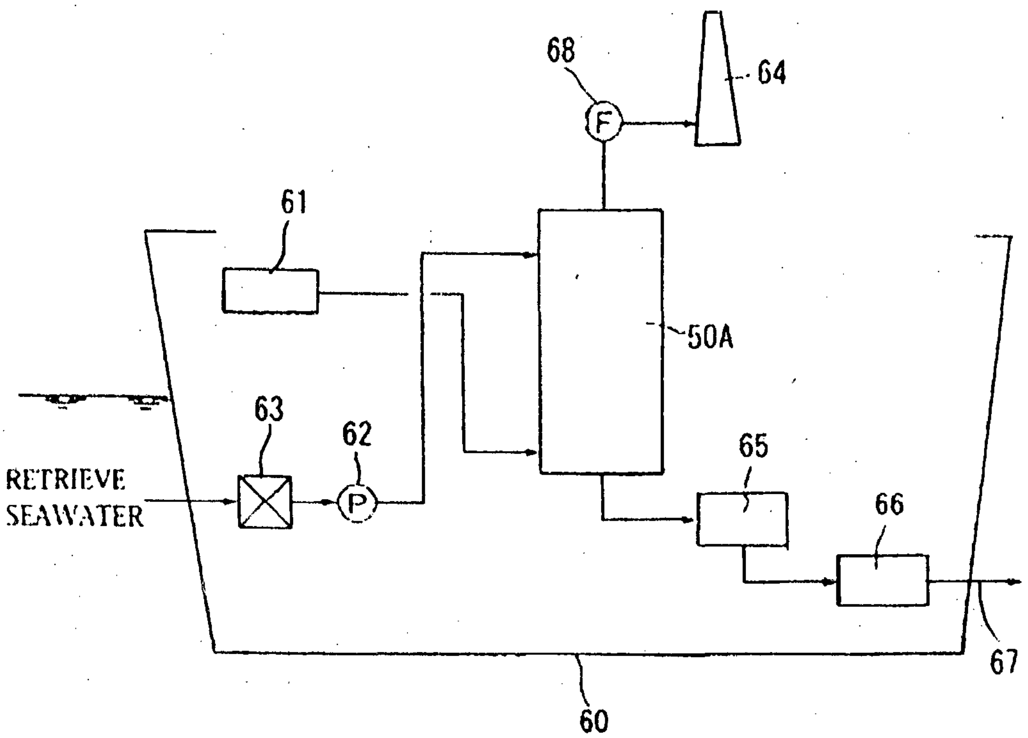

Figure 17

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