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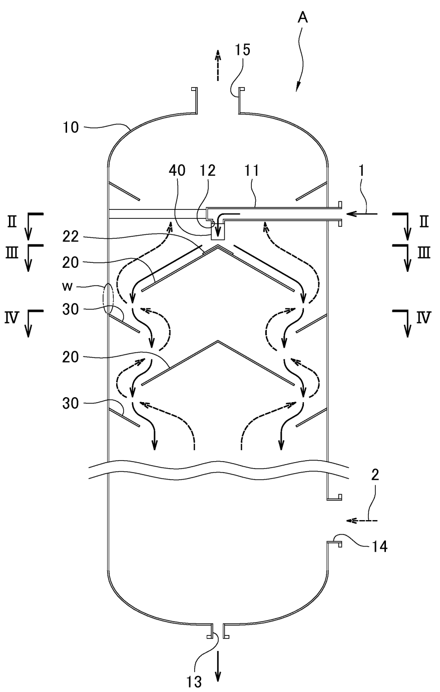
(54) COUNTERCURRENT-TYPE DIRECT HEATING HEAT EXCHANGER

(57) To provide a countercurrent direct-heating heat exchanger capable of suppressing wear of a container caused by a heating target fluid. A countercurrent direct-heating heat exchanger A includes: a container 10; a flow guide 40 connected to an inlet 12 for a heating target fluid 1 and guiding the heating target fluid 1 to flow in a vertically downward direction; and an umbrella-shape distribution plate 20 having a top arranged vertically below the flow guide 40. The flow guide 40 can suppress deflection of the heating target fluid 1. Thus, the heating target fluid 1 flows down to the top or the vicinity of the top of the umbrella-shape distribution plate 20 and is distributed uniformly in all directions of the umbrella-shape distribution plate 20. The amount of the heating target fluid 1 to contact the side wall of the container 10 is not increased locally to allow suppression of the wear of the container 10 caused by the heating target fluid 1.

F I G. 1



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Description

Technical Field

[0001] This invention relates to a countercurrent direct-heating heat exchanger. More specifically, this invention relates to a countercurrent direct-heating heat exchanger that exchanges heat by making a heating target fluid and a heating medium contact each other directly while flowing the heating target fluid into the heat exchanger from an upper part thereof and flowing the heating target fluid out of the heat exchanger from a lower part thereof, and simultaneously, flowing the heating medium into the heat exchanger from a lower part thereof and flowing the heating medium out of the heat exchanger from an upper part thereof.

Background Art

[0002] High-temperature and pressure sulfuric acid leaching, which is high pressure acid leaching (HPAL) using sulfuric acid, is known as hydrometallurgy to recover a valuable metal such as nickel or cobalt, etc. from a low-grade nickel oxide ore represented by a limonite ore, etc.

[0003] Hydrometallurgy by means of high-temperature and pressure sulfuric acid leaching includes a pretreatment step and a high-temperature and pressure sulfuric acid leaching step. In the pretreatment step, a nickel oxide ore is crushed and classified to manufacture an ore slurry. In the high-temperature and pressure sulfuric acid leaching step, the ore slurry is charged into an autoclave and then leaching process is performed under a leaching condition such as a temperature or a pressure selected, as necessary.

[0004] To maintain a high leaching rate, a temperature from about 200 to about 300°C is generally selected as a condition for leaching in the autoclave. Meanwhile, the ore slurry manufactured in the pretreatment step is placed at a temperature substantially the same as an outside air temperature. Hence, charging the ore slurry at this temperature as it is into the autoclave not only reduces a temperature in the autoclave to reduce a leaching rate but also causes an unstable temperature condition to make it difficult to produce stable leaching reaction. A responsive method having been employed is to make the temperature of the ore slurry approach a temperature in the autoclave by preheating the ore slurry and then charge the preheated ore slurry into the autoclave.

[0005] A countercurrent direct-heating heat exchanger is used as a preheating facility for an ore slurry (patent literature 1). The countercurrent direct-heating heat exchanger exchanges heat by making a heating target fluid (ore slurry) and a heating medium (water vapor) contact each other directly while flowing the heating target fluid into the heat exchanger from an upper part thereof and flowing the heating target fluid out of the heat exchanger from a lower part thereof, and simultaneously, flowing the heating medium into the heat exchanger from a lower part thereof and flowing the heating medium out of the heat exchanger from an upper part thereof.

Prior Art Literature

Patent Literature

[0006] Patent Literature 1: Japanese Patent Application Publication No. 2010-25455

Summary of Invention

Problem to be Solved by Invention

[0007] Using the countercurrent direct-heating heat exchanger for hearing an ore slurry may cause wear of the side wall of a container of the countercurrent direct-heating heat exchanger by the ore slurry.

[0008] In view of the foregoing circumstances, this invention is intended to provide a countercurrent direct-heating heat exchanger capable of suppressing wear of a container caused by a heating target fluid.

Means of Solving Problem

[0009] A countercurrent direct-heating heat exchanger according to a first invention includes: a container; a supply pipe through which a heating target fluid is supplied into the container; an inlet provided at an end portion of the supply pipe; a flow guide connected to the inlet and guiding the heating target fluid to flow in a vertically downward direction; and an umbrella-shape distribution plate having a top arranged vertically below the flow guide. The flow guide includes: a cylindrical body; and a partitioning member that partitions the interior of the cylindrical body into a plurality of flow paths extending along the center axis of the cylindrical body.

[0010] The countercurrent direct-heating heat exchanger according to a second invention is characterized in that, in the first invention, a slit is formed at the cylindrical body, the partitioning member includes an insertion plate, and the insertion plate is inserted into the slit and the slit and the inserted insertion plate are welded.

[0011] The countercurrent direct-heating heat exchanger according to a third invention is characterized in that, in the first or second invention, the flow guide includes a blocking member arranged on the center axis of the flow guide and blocking the flow of the heating target fluid.

[0012] The countercurrent direct-heating heat exchanger according to a fourth invention is characterized in that, in the first, second, or third invention, the umbrella-shape distribution plate is covered by a sacrificial member at the top and the vicinity of the top.

[0013] The countercurrent direct-heating heat exchanger according to a fifth invention is characterized in that, in the first, second, third, or fourth invention, the flow guide is connected in a removable manner to the inlet.

[0014] The countercurrent direct-heating heat exchanger according to a sixth invention is characterized in that, in the first, second, third, fourth, or fifth invention, a distance between an opening of the flow guide and the top of the umbrella-shape distribution plate is from 1. 1 to 1.3 times the diameter of the flow guide.

[0015] The countercurrent direct-heating heat exchanger according to a seventh invention is characterized in that, in the first, second, third, fourth, fifth, or sixth invention, the supply pipe is arranged substantially horizontally.

[0016] The countercurrent direct-heating heat exchanger according to an eighth invention is characterized in that, in the first, second, third, fourth, fifth, sixth, or seventh invention, the heating target fluid is a slurry.

Advantageous Effects of Invention

[0017] According to the first invention, the flow guide can suppress deflection of the heating target fluid. Thus, the heating target fluid flows down to the top or the vicinity of the top of the umbrella-shape distribution plate and is distributed uniformly in all directions of the umbrella-shape distribution plate. As a result, the amount of the heating target fluid to contact the side wall of the container is not increased locally to allow suppression of the wear of the container caused by the heating target fluid.

[0018] According to the second invention, the tight joint by welding between the cylindrical body and the partitioning member can function to stand against resistance produced by the flow of the heating target fluid to reduce the probability of damage of the flow guide.

[0019] According to the third invention, the flow velocity of the heating target fluid vertically below the blocking member is restricted. As a result, collision of the heating target fluid with the top of the umbrella-shape distribution plate can be weakened to allow reduction in damage of the umbrella-shape distribution plate.

[0020] According to the fourth invention, the sacrificial member receives impact caused by flowing down of the heating target fluid. In this way, wear of the umbrella-shape distribution plate can be suppressed.

[0021] According to the fifth invention, as the flow guide is removable, the flow guide can be exchanged or repaired easily.

[0022] According to the sixth invention, the distance between the flow guide and the umbrella-shape distribution plate is 1. 1 times the diameter of the flow guide or more. This causes the heating target fluid to flow smoothly to weaken rubbing between the heating target fluid and the umbrella-shape distribution plate. Thus, wear of the umbrella-shape distribution plate can be suppressed. The distance between the flow guide and the umbrella-shape distribution plate does not exceed 1.3 times the diameter of the flow guide. Thus, a direction in which the heating target fluid flows down from the flow guide is unlikely to be changed by the flow of a heating medium.

[0023] According to the seventh invention, even if the heating target fluid flows in the supply pipe in the horizontal direction, the flow guide can still guide the heating target fluid to flow in a vertically downward direction.

[0024] According to the eighth invention, even if the heating target fluid is a slurry, wear of the container caused by the heating target fluid can still be suppressed.

Brief Description of Drawings

[0025]

Fig. 1 is a longitudinal sectional view of a countercurrent direct-heating heat exchanger A according to an embodiment of this invention.

Fig. 2 is a sectional view taken along an arrow line II-II of Fig. 1

Fig. 3 is a sectional view taken along an arrow line III-III of Fig. 1. Hatching shows an umbrella-shape distribution plate 20.

Fig. 4 is a sectional view taken along an arrow line IV-IV of Fig. 1. Hatching shows an annular flow guide plate 30.

Fig. 5 is an enlarged view showing an inlet 12 and its vicinity in the absence of a flow guide 40.

Fig. 6A is a longitudinal sectional view of the flow guide 40. Fig. 6B is a plan view of the flow guide 40.

Fig. 7 is a perspective view of the flow guide 40.

Fig. 8 is an enlarged view of the flow guide 40 and its vicinity.

Fig. 9A is a transverse sectional view of the flow guide 40 according to a different embodiment. Fig. 9B is a transverse sectional view of the flow guide 40 according to a still different embodiment.

Fig. 10A shows a simulation result about the concentration distribution of a slurry. Fig. 10B is a simulation result about the flow velocity distribution of the slurry.

Fig. 11 is an entire process drawing of hydrometallurgy.

Embodiment for Carrying Out Invention

[0026] An embodiment of this invention will be described next by referring to the drawings.

(Hydrometallurgy)

[0027] A countercurrent direct-heating heat exchanger A according to an embodiment of this invention is used for hydrometallurgy to obtain nickel-cobalt mixed sulfide from a nickel oxide ore using high-temperature and pressure sulfuric acid leaching. As shown in Fig. 11, the hydrometallurgy includes a pretreatment step (101), a high-temperature and pressure sulfuric acid leaching step (102), a solid-liquid separating step (103), a neutralizing step (104), a dezincification step (105), a sulfurizing step (106), and a detoxifying step (107).

[0028] An ore to be used as a nickel oxide ore as a raw material is mainly what is called a laterite ore such as a limonite ore and a saprolite ore, for example. A nickel content in the laterite ore is generally from 0.5 to 3.0% by mass. The laterite ore contains nickel in the form of hydroxide or a siliceous magnesia (magnesium silicate) ore. An iron content in the laterite ore is from 10 to 50% by mass. The laterite ore contains iron mainly in the form of trivalent hydroxide (goethite, FeOOH) and partially in the form of divalent iron as a magnesium silicate ore.

[0029] In the pretreatment step (101), the nickel oxide ore is crushed, classified into an average particle size of 2 mm or less, and then slurried to manufacture an ore slurry. Redundant water in the ore slurry is removed using a solid-liquid separating device such as a thickener to concentrate the ore slurry so as to obtain a predetermined concentration of a solid in the ore slurry. In the high-temperature and pressure sulfuric acid leaching step (102), sulfuric acid is added to the ore slurry obtained in the pretreatment step (101). Then, the ore slurry is agitated under a temperature condition from 200 to 300°C for high-temperature and pressure acid leaching, thereby obtaining a leached slurry. In the solid-liquid separating step (103), the leached slurry obtained in the high-temperature and pressure sulfuric acid leaching step (102) is separated into a solid and a liquid to obtain a leachate containing nickel and cobalt (hereinafter called a "crude nickel sulfate solution") and a leaching residue.

[0030] In the neutralizing step (104), the crude nickel sulfate solution obtained in the solid-liquid separating step (103) is neutralized. In the dezincification step (105), hydrogen sulfide gas is added to the crude nickel sulfate solution neutralized in the neutralizing step (104) to remove zinc as a precipitate of zinc sulfide. In the sulfurizing step (106), hydrogen sulfide gas is added to final solution resulting from the dezincification obtained in the dezincification step (105) to obtain nickel-cobalt mixed sulfide and nickel barren solution. In the detoxifying step (107), the leaching residue generated in the solid-liquid separating step (103) and the nickel barren solution generated in the sulfurizing step (106) are detoxified.

[0031] A solid concentration in the ore slurry (weight ratio of a solid (ore) in the slurry) manufactured in the pretreatment step (101) depends largely on the properties of the nickel oxide ore as a raw material. Although not particularly limited, the concentration of a solid in the ore slurry is controlled in such a manner that the solid represents from 20 to 50% by mass. If a concentration in the ore slurry is less than 20% by mass, a large facility should be prepared for obtaining given time of stay during leaching and the amount of acid to be added should be increased for adjusting a residual acid concentration. Additionally, a nickel concentration in a resultant leachate is reduced. By contrast, if a solid concentration in the ore slurry exceeds 50% by mass, the scale of a facility can be reduced. However, such a solid concentration increases the viscosity of the ore slurry to make it difficult to carry the ore slurry due to blockage of a carrier pipe or large energy required for carrying the ore slurry.

[0032] The high-temperature and pressure sulfuric acid leaching step (102) includes two sub-steps (a preheating step and a leaching step). In the preheating step, the ore slurry at a temperature about an outside air temperature carried from the pretreatment step (101) is preheated to make the temperature of the ore slurry approach a temperature in an autoclave to be used in the leaching step. In the leaching step, the ore slurry carried from the preheating step is charged into the autoclave. Then, leaching is performed by adding sulfuric acid to the ore slurry and blowing high-pressure air and high-pressure water vapor into the autoclave.

[0033] The countercurrent direct-heating heat exchanger A of this embodiment is used for heating the ore slurry in the preheating step. If necessary, two or more countercurrent direct-heating heat exchangers A are connected in series and the ore slurry is heated in stages.

[0034] To maintain a moisture content in the ore slurry, the countercurrent direct-heating heat exchanger A uses water vapor as a heating medium. Water vapor to be used may be generated by using a common method such as a boiler. For ejection of a leached slurry from the autoclave, pressure is reduced in stages using a pressure reducing container. Water vapor generated in this pressure reducing container may be collected and used as a heating medium in the countercurrent direct-heating heat exchanger A.

(Countercurrent Direct-Heating Heat Exchanger A)

[0035] The countercurrent direct-heating heat exchanger A according to this embodiment will be described next.

[0036] The countercurrent direct-heating heat exchanger A is a heat exchanger that exchanges heat by flowing a heating target fluid 1 and a heating medium 2 in opposite directions and making the heating target fluid 1 and the heating medium 2 contact each other directly. In this embodiment, the heating target fluid 1 is an ore slurry 1 obtained in the pretreatment step (101) of the foregoing hydrometallurgy and the heating medium 2 is water vapor 2.

[0037] As shown in Fig. 1, the countercurrent direct-heating heat exchanger A includes a substantially circular cylindrical container 10. The container 10 is arranged vertically in such a manner that the center axis of the container 10 extends in the vertical direction.

[0038] The container 10 is provided with a supply pipe 11 arranged substantially horizontally at an upper part of the container 10. A heating target fluid inlet 12 is provided at an end portion of the supply pipe 11 to be pointed vertically downwardly. A flow guide 40 is connected to the heating target fluid inlet 12. The container 10 is provided with a heating target fluid outlet 13 arranged at a lower part, more specifically, at the bottom of the container 10. The ore slurry 1 as the heating target fluid 1 is supplied into the container 10 through the supply pipe

11, passes through the heating target fluid inlet 12, and flows down from an opening (lower end) of the flow guide 40. Then, the ore slurry 1 flows down in the container 10 and is ejected to the outside of the container 10 from the heating target fluid outlet 13.

[0039] Solid arrows of Fig. 1 show a flow of the ore slurry 1. The heating target fluid inlet 12 corresponds to an "inlet" recited in the appended claims. The heating target fluid inlet 12 will simply be called an inlet 12.

[0040] The container 10 is provided with a heating medium inlet 14 arranged at a lower side wall of the container 10. The container 10 is provided with a heating medium outlet 15 arranged at an upper part, more specifically, at the top of the container 10. The water vapor 2 as the heating medium 2 is supplied from the heating medium inlet 14 into the container 10. The supplied water vapor 2 moves up in the container 10 and is then ejected to the outside of the container 10 from the heating medium outlet 15. Dashed arrows of Fig. 1 show a flow of the water vapor 2.

[0041] The container 10 is provided with a plurality of umbrella-shape distribution plates 20 and a plurality of annular flow guide plates 30. The umbrella-shape distribution plates 20 and the annular flow guide plates 30 are arranged alternately, one above the other, with the respective centers being substantially aligned with each other. These umbrella-shape distribution plates 20 and these annular flow guide plates 30 each have a tilted surface. The ore slurry 1 supplied into the container 10 flows down along the respective tilted surfaces of the umbrella-shape distribution plates 20 and those of the annular flow guide plates 30 to drop down from downstream edge portions of the tilted surfaces. By making this flow repeatedly, the ore slurry 1 flows down in the container 10. Meanwhile, the water vapor 2 supplied into the container 10 moves up in the container 10 while passing through between the umbrella-shape distribution plates 20 and the annular flow guide plates 30 in a zigzag manner.

[0042] As shown in Fig. 2, in a plan view, the supply pipe 11 is arranged to extend in the direction of the diameter of the container 10 from the side wall to a substantially central point of the container 10. The inlet 12 is formed at an end portion of the supply pipe 11. The inlet 12 is arranged at a substantially central point of the container 10 in a plan view. Thus, the flow guide 40 is also arranged at a substantially central point of the container 10 in a plan view. The supply pipe 11 is supported by a beam 11a extending linearly from the end portion of the supply pipe 11 to the side wall of the container 10.

[0043] As shown in Figs. 1 and 3, the umbrella-shape distribution plate 20 is a tilted plate having an umbrella shape (conical shape). The umbrella-shape distribution plate 20 is arranged in such a manner that the top of the umbrella-shape distribution plate 20 is pointed upwardly and the top (center) substantially agrees with the center of the container 10 in a plan view. The top of the umbrella-shape distribution plate 20 is arranged vertically below the flow guide 40. Thus, the ore slurry 1 is supplied from the flow guide 40 to the top of the umbrella-shape distribution plate 20 in a top layer, distributed radially along the tilted surface of the umbrella-shape distribution plate 20, and drops down in a skirt-like manner from a downstream edge portion 21. The downstream edge portion 21 of the umbrella-shape distribution plate 20 is an edge where the side surface and the bottom surface of a cone contact each other.

[0044] The umbrella-shape distribution plate 20 in the top layer is covered by a sacrificial member 22 at the top and the vicinity of the top. The sacrificial member 22 may be formed by hardfacing or using a material having a strength such as a steel sheet.

[0045] As shown in Figs. 1 and 4, the annular flow guide plate 30 is an annular tilted plate having a slope descending from the outer peripheral edge toward the inner peripheral edge of the annular flow guide plate 30. The outer diameter of the annular flow guide plate 30 is substantially the same as the inner diameter of the container 10. The outer peripheral edge of the annular flow guide plate 30 contacts the inner wall of the container 10. The annular flow guide plate 30 is arranged in such a manner that the center of the annular flow guide plate 30 (the respective centers of the outer periphery and the inner periphery) substantially agrees with the center of the container 10 in a plan view. After dropping down from the umbrella-shape distribution plate 20 to the annular flow guide plate 30, the ore slurry 1 flows down along the tilted surface toward the center of the annular flow guide plate 30 and then drops down in a skirt-like manner from a downstream edge portion 31. The downstream edge portion 31 of the annular flow guide plate 30 is the inner peripheral edge thereof.

(Heat Exchange by Countercurrent Direct-Heating Heat Exchanger A)

[0046] Heat exchange by the countercurrent direct-heating heat exchanger A will be described next.

[0047] The ore slurry 1 is supplied into the container 10 from the flow guide 40. The ore slurry 1 supplied into the container 10 first flows down radially along the tilted surface of the umbrella-shape distribution plate 20 in the top layer and then drops down in a skirt-like manner from the downstream edge portion 21. After dropping down from the umbrella-shape distribution plate 20 to the annular flow guide plate 30, the ore slurry 1 flows down along the tilted surface toward the center of the annular flow guide plate 30 and then drops down in a skirt-like manner from the downstream edge portion 31. Then, the ore slurry 1 drops down to the umbrella-shape distribution plate 20 in a subsequent layer. In this way, the ore slurry 1 flows down along the respective tilted surfaces of the umbrella-shape distribution plate 20 and the annular flow guide plate 30 alternately and is then ejected to the outside of the container 10 from the heating target fluid outlet 13 at the lower part of the container 10.

[0048] The water vapor 2 is supplied into the container 10 from the heating medium inlet 14 at the lower part of the container 10, moves up while passing through between the umbrella-shape distribution plate 20 and the annular flow guide plate 30 in a zigzag manner, and is then ejected to the outside of the container 10 from the heating medium outlet 15 at the upper part of the container 10. During this flow, the water vapor 2 contacts the ore slurry 1 directly by flowing along the ore slurry 1 while the ore slurry 1 flows down along the respective tilted surfaces of the umbrella-shape distribution plate 20 and the annular flow guide plate 30. The water vapor 2 also contacts the ore slurry 1 directly by passing through the ore slurry 1 while the ore slurry 1 drops down from the downstream edge portions 21 and 31 of the umbrella-shape distribution plate 20 and the annular flow guide plate 30 respectively. In this way, heat is exchanged between the ore slurry 1 and the water vapor 2.

[0049] As described above, the countercurrent direct-heating heat exchanger A exchanges heat by making the ore slurry 1 and the water vapor 2 contact each other directly while flowing the ore slurry 1 into the heat exchanger A from an upper part thereof and flowing the ore slurry 1 out of the heat exchanger A from a lower part thereof, and simultaneously, flowing the water vapor 2 into the heat exchanger A from a lower part thereof and flowing the water vapor 2 out of the heat exchanger A from an upper part thereof.

[0050] The ore slurry 1 is distributed radially along the umbrella-shape distribution plate 20. This increases an area of contact between the ore slurry 1 and the water vapor 2 to increase heat exchange efficiency. Further, the flow of the water vapor 2 is guided along the annular flow guide plate 30 and the water vapor 2 flows along the ore slurry 1 while the ore slurry 1 flows down along the tilted surface of the umbrella-shape distribution plate 20. This also increases an area of contact between the ore slurry 1 and the water vapor 2 to increase heat exchange efficiency.

(Flow Guide 40)

[0051] The flow guide 40 forming a characteristic part of this embodiment will be described in detail next.

[0052] Fig. 5 is an enlarged view showing the inlet 12 and its vicinity in the absence of the flow guide 40. Alternate long and two short dashes lines O in Fig. 5 show a vertical line passing through the center of the inlet 12.

[0053] In the absence of the flow guide 40, the ore slurry 1 flows in a substantially horizontal direction in the supply pipe 11 and then flows down from the inlet 12. The ore slurry 1 is under the force of gravity while flowing down from the inlet 12, so that the ore slurry 1 flows in a direction downward from the horizontal direction.

[0054] Meanwhile, the ore slurry 1 still has momentum in the horizontal direction generated during the flow of the ore slurry 1 in the supply pipe 11. Hence, a direction in which the ore slurry 1 flows down from the inlet 12 is tilted from a vertically downward direction. The ore slurry 1 is tilted in a direction in which the supply pipe 11 extends (leftward direction of Fig. 5). In this description, a phenomenon where such a tilt of the flow direction of the ore slurry 1 from the vertically downward direction occurs when the ore slurry 1 flows down from the inlet 12 is called "deflection."

[0055] On the occurrence of the deflection, a part of the ore slurry 1 flowing along the tilted surface of the umbrella-shape distribution plate 20 and flowing in the direction of the deflection (direction in which the supply pipe 11 extends) has greater momentum than a part of the ore slurry 1 flowing in a different direction. This part of the ore slurry 1 having greater momentum drops down from the downstream edge portion 21 of the umbrella-shape distribution plate 20 and then contacts the side wall of the container 10. Hence, a part of the side wall of the container 10 located in the direction of the deflection (part w of Fig. 1) is to contact the ore slurry 1 of a greater amount than a different part of the side wall. Specifically, the amount of the ore slurry 1 to contact the side wall of the container 10 is increased locally. As a result, the part of the side wall of the container 10 (part w) is more likely to be worn out by the ore slurry 1 than a different part.

[0056] On the occurrence of the deflection, the ore slurry 1 is not distributed uniformly in all directions of the umbrella-shape distribution plate 20 to cause imbalance. As a result, heat exchange efficiency is reduced.

[0057] A deflection angle θ (an angle formed between a direction in which the ore slurry 1 flows and a vertical line O) changes in a manner that depends on the flow rate of the ore slurry 1, a slurry specific gravity, or a solid concentration. These parameters change during operation of the countercurrent direct-heating heat exchanger A. Thus, the deflection angle θ changes during the operation to change a position where the ore slurry 1 having flowed down from the inlet 12 collides with the umbrella-shape distribution plate 20. Apart of the umbrella-shape distribution plate 20 to collide with the ore slurry 1 having flowed down from the inlet 12 is likely to be damaged. If the deflection angle θ changes during the operation, flowing down of the ore slurry 1 may cause impact on a wide range of the umbrella-shape distribution plate 20. It is difficult to protect the umbrella-shape distribution plate 20 from such impact.

[0058] To solve the foregoing problem, the flow guide 40 is attached to the inlet 12. The flow guide 40 has the function of guiding the ore slurry 1 to flow in a vertically downward direction.

[0059] As shown in Figs. 6A, 6B, and 7, the flow guide 40 is constructed of a cylindrical body 41, a partitioning member 42, and a blocking member 43.

[0060] The cylindrical body 41 is a member having a circular cylindrical shape and includes a flange 41f at an upper end portion thereof. The flange 41f and a flange 12f of the inlet 12 are coupled with a bolt, a nut, etc., thereby attaching the flow guide 40 to the inlet 12.

[0061] The cylindrical body 41 is formed with four slits

41s each extending from the lower end toward a point near the vertical center of the cylindrical body 41. The slits 41s are formed at regular intervals (at intervals of 90 degrees) in the peripheral direction of the cylindrical body 41.

[0062] The partitioning member 42 is constructed of a pipe 42a of a small diameter, and eight partitioning plates 42b joined to the outer periphery of the pipe 42a. The partitioning plates 42b are arranged at regular intervals (at intervals of 45 degrees) in the peripheral direction of the pipe 42a. In a plan view of the partitioning member 42, the eight partitioning plates 42b are arranged in a radial pattern about the pipe 42a. The pipe 42a is arranged in such a manner that the center axis of the pipe 42a agrees with a center axis O of the flow guide 40. The partitioning plates 42b are flat plates and arranged to extend along the center axis O.

[0063] Four of the eight partitioning plates 42b have outer edge portions protruding from their lower ends toward their vertically central points. These protruding portions are called insertion plates 42c. The partitioning plates 42b with the insertion plates 42c and the partitioning plates 42b without the insertion plates 42c are arranged alternately. Specifically, the insertion plates 42c are arranged at intervals of 90 degrees in the peripheral direction of the pipe 42a.

[0064] The blocking member 43 is a member having a circular plate shape and has a diameter substantially the same as the outer diameter of the pipe 42a. The blocking member 43 is arranged on the center axis O of the flow guide 40 and joined to the upper end of the pipe 42a. The upper end of the pipe 42a is sealed by the blocking member 43. The flow of the ore slurry 1 is blocked in a part in which the blocking member 43 is arranged. Thus, the flow of the ore slurry 1 is blocked at the center axis O and its vicinity of the flow guide 40.

[0065] As shown in Fig. 7, the flow guide 40 is assembled by the following procedure. First, the partitioning member 42 is inserted from a lower opening of the cylindrical body 41. At this time, the insertion plates 42c of the partitioning member 42 are inserted into the slits 41s of the cylindrical body 41. Then, the slits 41s and the insertion plates 42c are welded.

[0066] By assembling the flow guide 40 in this way, the cylindrical body 41 and the partitioning member 42 are tightly joined by welding. If the ore slurry 1 passes through in the flow guide 40, resistance (friction or impact) acts between the ore slurry 1 and the partitioning member 42 to produce force of pressing the partitioning member 42 downwardly. Meanwhile, the tight joint between the cylindrical body 41 and the partitioning member 42 can function to stand against the downwardly acting force produced by the flow of the ore slurry 1, reducing the probability of damage of the flow guide 40.

[0067] The foregoing method is not a limited method of assembling the flow guide 40. A configuration of inserting the insertion plates 42c into the slits 41s may not be employed. The flow guide 40 may be assembled simply by welding the inner surface of the cylindrical body 41 and the outer edge portions of the partitioning plates 42b. Alternatively, the cylindrical body 41 and the partitioning member 42 may be fixed by a different method such as fastening with a screw.

[0068] As shown in Fig. 6B, the interior of the cylindrical body 41 is partitioned into eight flow paths 44 by the partitioning member 42. Both the pipe 42a and the partitioning plates 42b are arranged to extend along the center axis O, so that each flow path 44 extends along the center axis O.

[0069] The ore slurry 1 flows in a distributed manner through the plurality of flow paths 44 extending along the center axis O of the flow guide 40. This makes it possible to guide the ore slurry 1 to flow in a direction along the center axis O of the flow guide 40.

[0070] As shown in Fig. 8, the flow guide 40 is arranged in such a manner that the center axis O of the flow guide 40 substantially agrees with the vertical line passing through the center of the inlet 12. The inlet 12 is arranged at the substantially central point of the container 10, so that the center axis O of the flow guide 40 also substantially agrees with the center axis of the container 10. Thus, after the ore slurry 1 passes through the flow guide 40, the ore slurry 1 flows vertically downwardly along the center axis of the container 10. Even if the ore slurry 1 flows in the supply pipe 11 in the horizontal direction, the flow guide 40 can still guide the ore slurry 1 to flow in a vertically downward direction. In this way, the flow guide 40 can suppress the deflection of the ore slurry 1.

[0071] The deflection of the ore slurry 1 can be suppressed. Thus, the ore slurry 1 flows down to the top or the vicinity of the top of the umbrella-shape distribution plate 20 in the top layer and is distributed uniformly in all directions of the umbrella-shape distribution plate 20. This prevents the momentum of the ore slurry 1 flowing along the tilted surface of the umbrella-shape distribution plate 20 from increasing locally. The amount of the ore slurry 1 to contact the side wall of the container 10 is not increased locally to allow suppression of the wear of the container 10 caused by the ore slurry 1.

[0072] The ore slurry 1 is distributed uniformly in all directions of the umbrella-shape distribution plate 20. This increases the heat exchange efficiency of the countercurrent direct-heating heat exchanger A.

[0073] Even if the flow rate of the ore slurry 1, a slurry specific gravity, or a solid concentration changes, a direction in which the ore slurry 1 flows can still be maintained in a vertically downward direction. Thus, the ore slurry 1 always collides with the top or the vicinity of the top of the umbrella-shape distribution plate 20 and this position does not change. Covering the top and the vicinity of the top of the umbrella-shape distribution plate 20 in the top layer with the sacrificial member 22 makes the sacrificial member 22 receive impact caused by flowing down of the ore slurry 1. In this way, wear of the umbrella-shape distribution plate 20 can be suppressed. As a result, the lifetime of the umbrella-shape distribution plate 20 can be extended.

[0074] The blocking member 43 is provided on the center axis O of the flow guide 40. The top of the umbrella-shape distribution plate 20 is arranged vertically below the blocking member 43. By the presence of the blocking member 43, the flow rate (flow velocity) of the ore slurry 1 vertically below the blocking member 43 can be restricted. As a result, collision of the ore slurry 1 with the top of the umbrella-shape distribution plate 20 in the top layer can be weakened to allow reduction in damage of the umbrella-shape distribution plate 20.

[0075] The flow guide 40 causes the ore slurry 1 to pass through, so that the flow guide 40 is worn out easily. After long-time use of the flow guide 40, the flow guide 40 should be exchanged or repaired. The flow guide 40 is attached to the inlet 12 at the flange 41f as described above, so that the flow guide 40 is removable. As the flow guide 40 is removable, even if the flow guide 40 is worn out, the flow guide 40 can be exchanged or repaired easily.

[0076] A distance H between the opening at the lower end of the flow guide 40 and the top of the umbrella-shape distribution plate 20 in the top layer is preferably from 1. 1 to 1.3 times a diameter D of the flow guide 40.

[0077] If the distance H is less than 1.1 times the diameter D, the ore slurry 1 is accumulated at an exit of the flow guide 40. In this case, the ore slurry 1 rubs vigorously against the umbrella-shape distribution plate 20. As a result, the umbrella-shape distribution plate 20 becomes likely to be worn out easily. Further, by the presence of the accumulated ore slurry 1, the ore slurry 1 in the flow guide 40 is decelerated to cause the risk of blockage of the flow guide 40 by the ore slurry 1. If the distance H is 1.1 times the diameter D or more, the ore slurry 1 is caused to flow smoothly to weaken rubbing between the ore slurry 1 and the umbrella-shape distribution plate 20. Thus, wear of the umbrella-shape distribution plate 20 can be suppressed.

[0078] If the distance H exceeds 1.3 times the diameter D, the ore slurry 1 having flowed down from the flow guide 40 is disturbed by the flow of the water vapor 2 to cause the risk of failing to maintain uniform distribution at the umbrella-shape distribution plate 20. Additionally, if the ore slurry 1 of a large amount exceeding the capability of the flow guide 40 to guide a flow is supplied, the ore slurry 1 may collide with the side wall of the container 10 directly without abutting on the umbrella-shape distribution plate 20. If the distance H does not exceed 1.3 times the diameter D, a direction in which the ore slurry 1 flows down from the flow guide 40 is unlikely to be changed by the flow of the water vapor 2. Further, the ore slurry 1 does not collide with the side wall of the container 10 directly.

[0079] An opening surface of the flow guide 40 is perpendicular to the center axis O. Thus, even if pressure in the flow guide 40 is higher than outside pressure, the ore slurry 1 can still be prevented from flying outwardly.

[Other Embodiments]

(Flow Guide 40)

[0080] As shown in Fig. 9A, the partitioning member 42 may be formed by tying a plurality of small-diameter pipes 42d together. The cross section of the small-diameter pipe 42d is not limited to a circular shape but may be a polygonal shape.

[0081] As shown in Fig. 9B, the partitioning member 42 may be formed by combining a plurality of partitioning plates 42e in a radial pattern. The number of the flow paths 44 in the cylindrical body 41 is not limited to eight but is required to be two or more. If the partitioning member 42 formed by combining the partitioning plates 42e in a cross shape is used, four flow paths 44 are formed.

[0082] Adjacent flow paths 44 may be partitioned completely by the partitioning member 42. The partitioning member 42 may include a communication part for making communication between the adjacent flow paths 44.

[0083] The blocking member 43 is required to be arranged on the center axis O of the flow guide 40. If the blocking member 43 having a circular plate shape is used, the upper part of the flow guide 40 is not a limited place for arrangement of the blocking member 43 but the blocking member 43 may be arranged at a lower part or a vertically central part of the flow guide 40.

[0084] The shape of the blocking member 43 is not limited to a circular plate shape but various shapes are applicable. The blocking member 43 may have a circular columnar shape or a conical shape. For example, the conical blocking member 43 is assembled into the partitioning member 42 with the top of the blocking member 43 pointed upwardly. This causes the ore slurry 1 to flow along a tilted surface of the blocking member 43. In this way, collision of the ore slurry 1 with the blocking member 43 and resultant dispersion of the ore slurry 1 can be suppressed.

(Heating Target Fluid 1)

[0085] The heating target fluid 1 is not particularly limited but is required to be a heating target having flowability. For example, the heating target fluid 1 may be liquid with flowability in the form of a slurry containing a solid component. The liquid with flowability in the form of a slurry may be a slurry (ore slurry) containing an ore. The ore slurry may be a slurry containing a nickel oxide ore obtained in the pretreatment step (101) of the hydrometallurgy, for example. Even if the heating target fluid 1 is a slurry, wear of the container 10 caused by the heating target fluid 1 can still be suppressed.

(Heating Medium 2)

[0086] The heating medium 2 is not particularly limited but is required to be a medium to supply heat to the heating target fluid 1. The heating medium 2 may be gas such as water vapor at a higher temperature than the heating target fluid 1.

Examples

(Simulation)

[0087] The supply pipe 11, the flow guide 40, and the umbrella-shape distribution plate 20 in the top layer were reproduced on a computer and the behavior of a slurry was simulated. The shape of the flow guide 40 shown in Figs. 6A and 6B was employed. Fig. 10A shows the concentration distribution of the slurry. Fig. 10B shows the flow velocity distribution of the slurry.

[0088] As understood from Fig. 10A, the concentration of the slurry is uniform and the slurry is distributed uniformly in all directions of the umbrella-shape distribution plate 20. As understood from Fig. 10B, the flow velocity of the slurry flowing down from the flow guide 40 is lower at the center and its vicinity than at an external point. This results from effect brought by the blocking member 43. The flow velocity of the slurry is found to be restricted at the top of the umbrella-shape distribution plate 20.

(Working Example 1)

[0089] In the preheating step of the foregoing hydrometallurgy, an ore slurry was heated using a countercurrent direct-heating heat exchanger. The countercurrent direct-heating heat exchanger has the same basic configuration as the countercurrent direct-heating heat exchanger A shown in Fig. 1.

[0090] The side wall of the container 10 of the countercurrent direct-heating heat exchanger is made of titanium of a thickness of 9 mm on an inner side and carbon steel of a thickness of 23.5 mm on an outer side. The side wall has a total thickness of 32.5 mm.

[0091] The flow guide 40 shown in Figs. 6A and 6B was attached to the inlet 12. The ore slurry 1 was supplied to the countercurrent direct-heating heat exchanger and operation was started.

[0092] The state of the interior of the countercurrent direct-heating heat exchanger was checked one year after start of the operation and no thickness reduction of the side wall of the container 10 was found. The state of the interior of the countercurrent direct-heating heat exchanger was checked two years after start of the operation and no thickness reduction of the side wall of the container 10 was found.

(Comparative Example 1)

[0093] The flow guide 40 used in Working Example 1 was replaced by a short pipe. The short pipe has dimensions similar to those of the cylindrical body 41 of the flow guide 40. The other conditions are the same as those of Working Example 1.

[0094] The state of the interior of the countercurrent direct-heating heat exchanger was checked one year after start of the operation and thickness reduction of the side wall of the container 10 was found. The state of the interior of the countercurrent direct-heating heat exchanger was checked two years after start of the operation and a pin hole appeared in the side wall of the container 10 due to further development of the thickness reduction.

[0095] As described above, Working Example 1 was found to be capable of suppressing wear of the side wall of the container 10. This is considered to be realized by the uniform flow of the ore slurry 1 in all directions of the umbrella-shape distribution plate 20 as a result of provision of the flow guide 40.

Reference Sings List

[0096]

A	Countercurrent direct-heating heat exchanger
1	Ore slurry
2	Water vapor
10	Container
11	Supply pipe
12	Inlet
20	Umbrella-shape distribution plate
22	Sacrificial member
30	Annular flow guide plate
40	Flow guide
41	Cylindrical body
42	Partitioning member
43	Blocking member

Claims

1. A countercurrent direct-heating heat exchanger comprising:

a container;
a supply pipe through which a heating target fluid is supplied into the container;
an inlet provided at an end portion of the supply pipe;
a flow guide connected to the inlet and guiding the heating target fluid to flow in a vertically downward direction; and
an umbrella-shape distribution plate having a top arranged vertically below the flow guide, wherein
the flow guide includes:

a cylindrical body; and
a partitioning member that partitions the interior of the cylindrical body into a plurality of flow paths extending along the center axis of the cylindrical body.

2. The countercurrent direct-heating heat exchanger according to claim 1, wherein
a slit is formed at the cylindrical body,
the partitioning member includes an insertion plate, and
the insertion plate is inserted into the slit and the slit and the inserted insertion plate are welded.

3. The countercurrent direct-heating heat exchanger according to claim 1 or 2, wherein
the flow guide includes a blocking member arranged on the center axis of the flow guide and blocking the flow of the heating target fluid.

4. The countercurrent direct-heating heat exchanger according to claim 1, 2, or 3, wherein
the umbrella-shape distribution plate is covered by a sacrificial member at the top and the vicinity of the top.

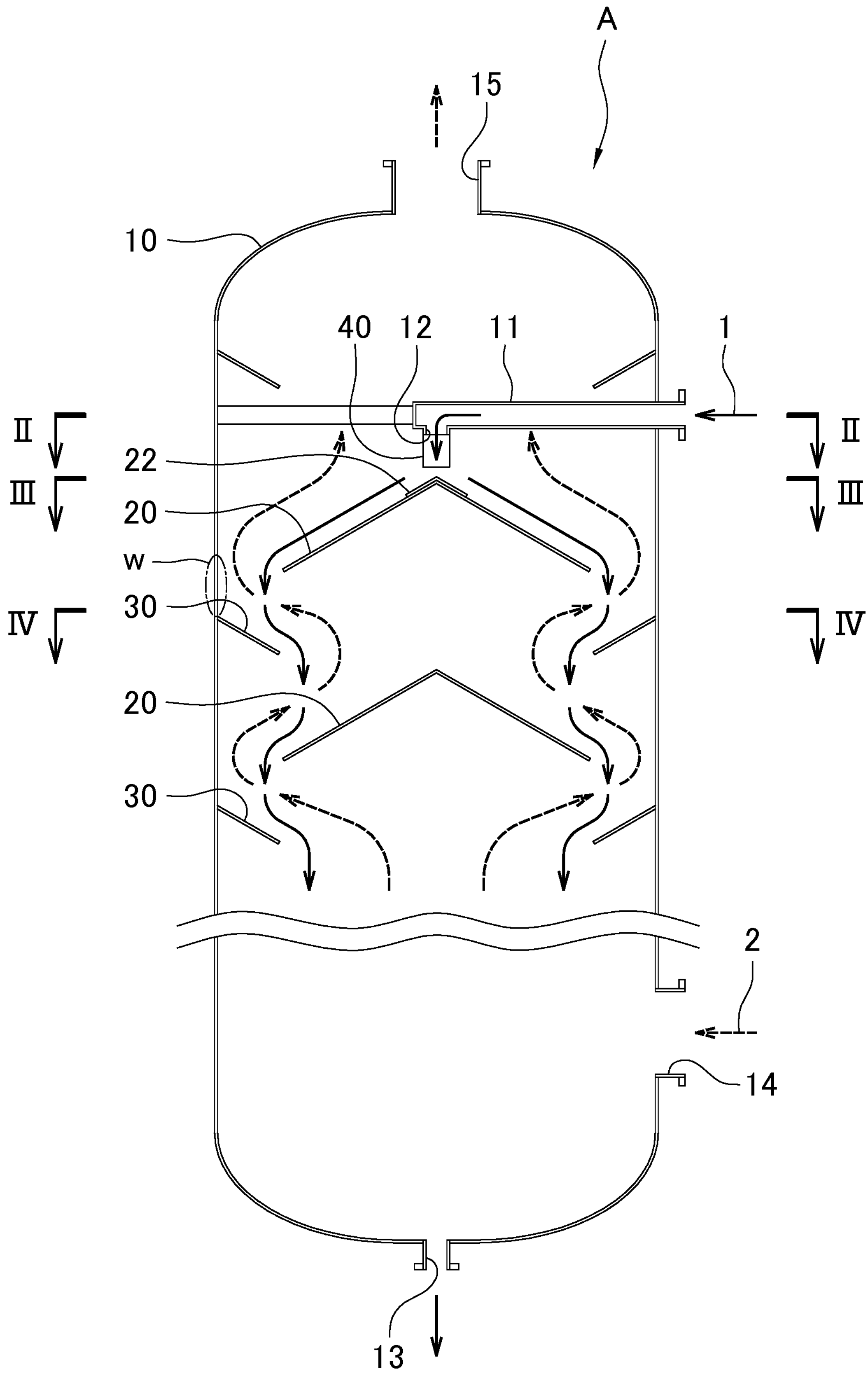
5. The countercurrent direct-heating heat exchanger according to claim 1, 2, 3, or 4, wherein
the flow guide is connected in a removable manner to the inlet.

6. The countercurrent direct-heating heat exchanger according to claim 1, 2, 3, 4, or 5, wherein
a distance between an opening of the flow guide and the top of the umbrella-shape distribution plate is from 1. 1 to 1.3 times the diameter of the flow guide.

7. The countercurrent direct-heating heat exchanger according to claim 1, 2, 3, 4, 5, or 6, wherein
the supply pipe is arranged substantially horizontally.

8. The countercurrent direct-heating heat exchanger according to claim 1, 2, 3, 4, 5, 6, or 7, wherein
the heating target fluid is a slurry.

FIG. 1



F I G. 2

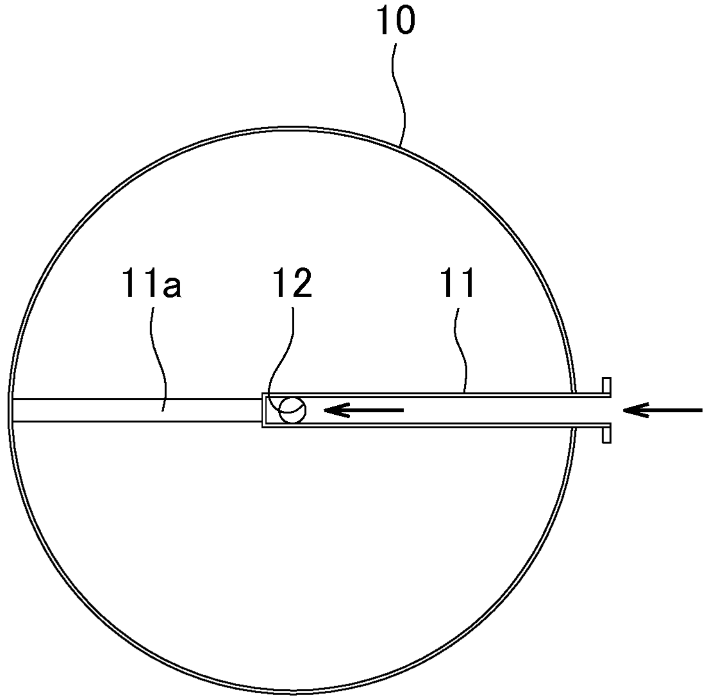


FIG. 3

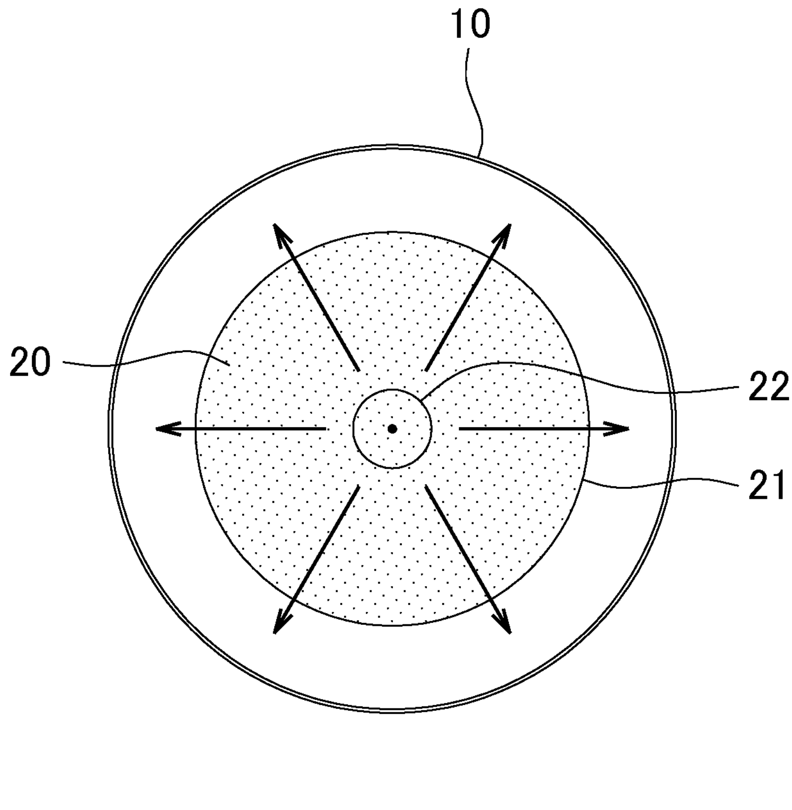
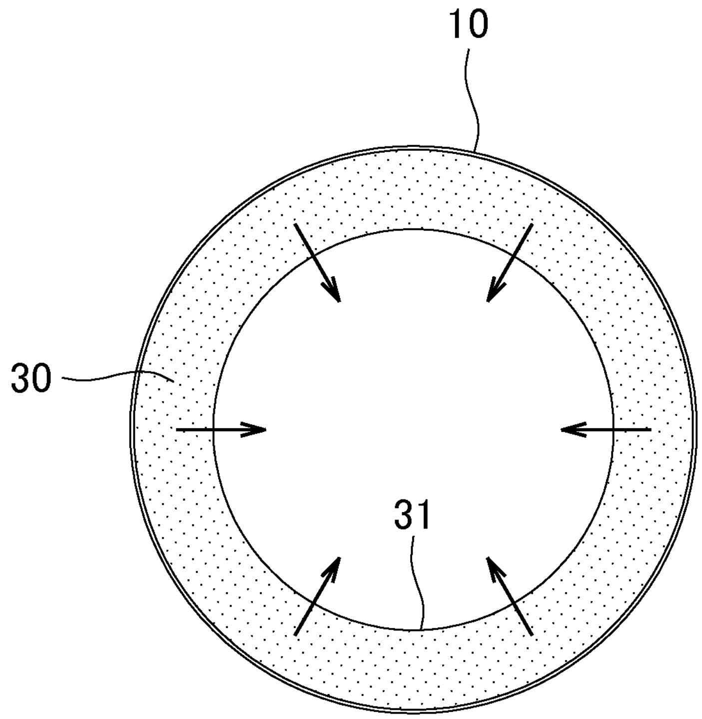
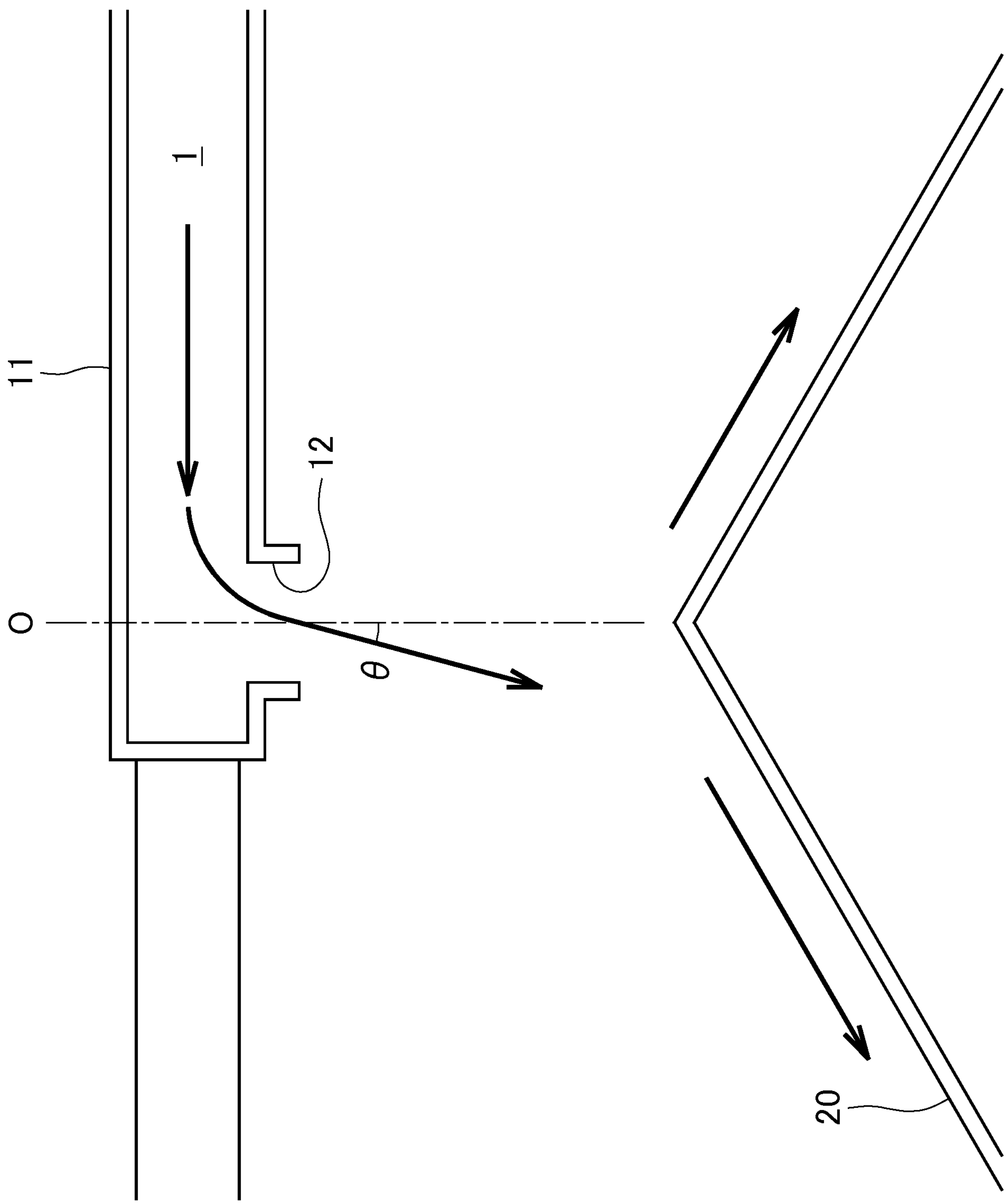


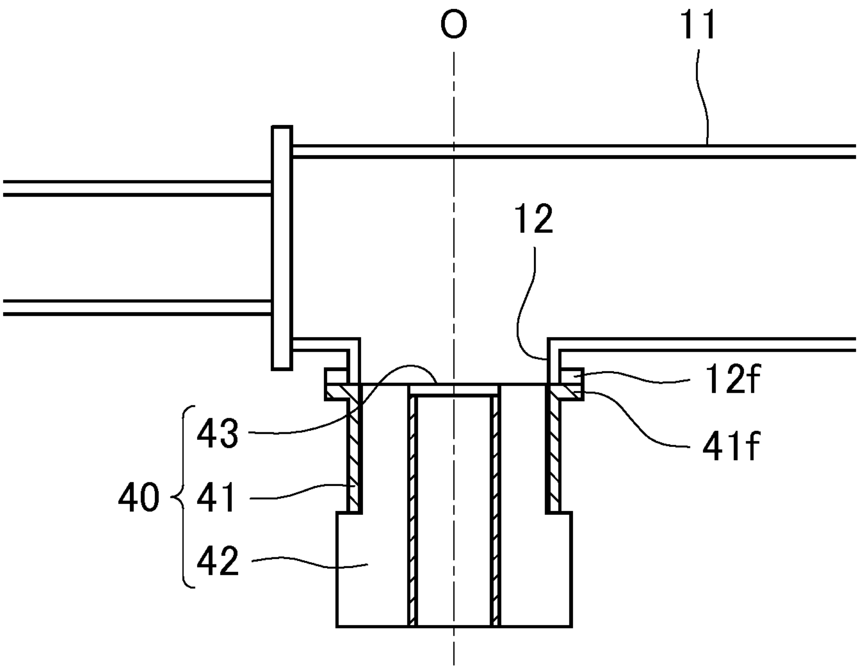
FIG. 4



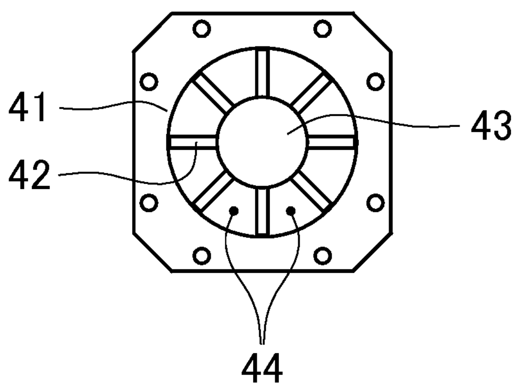
F I G. 5



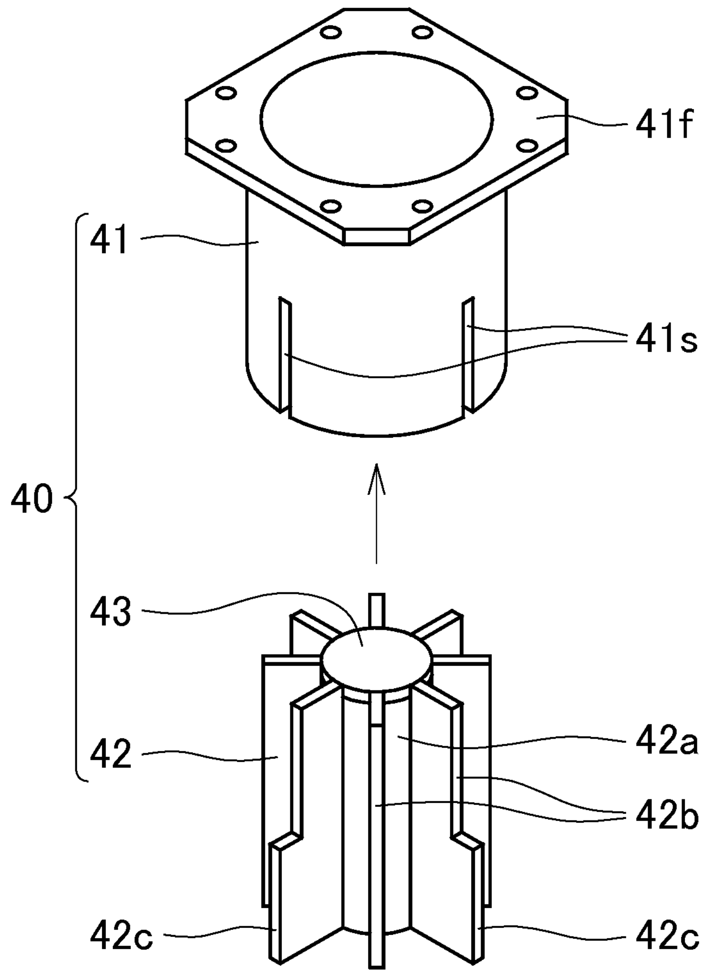
F I G. 6 A



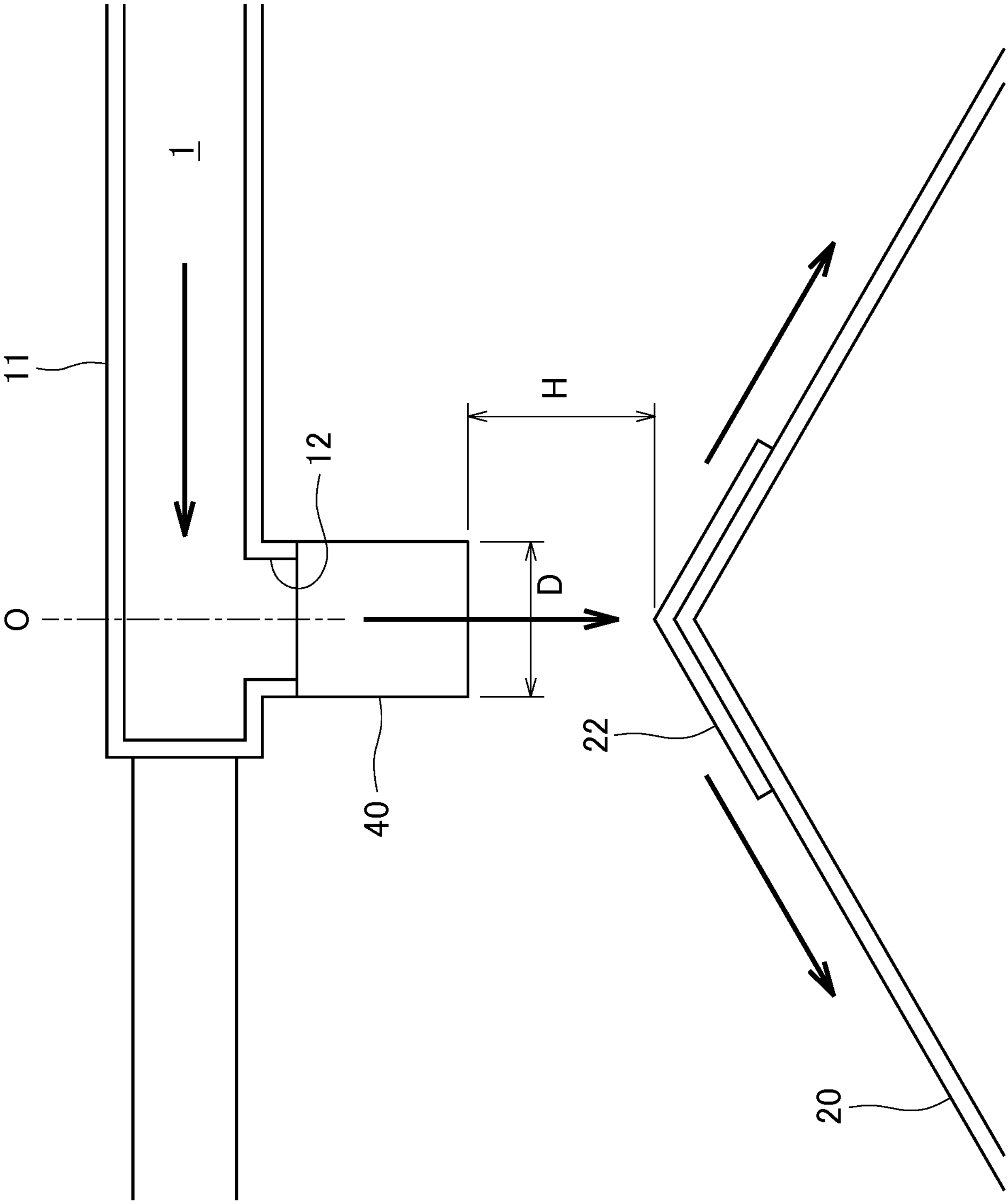
F I G. 6 B



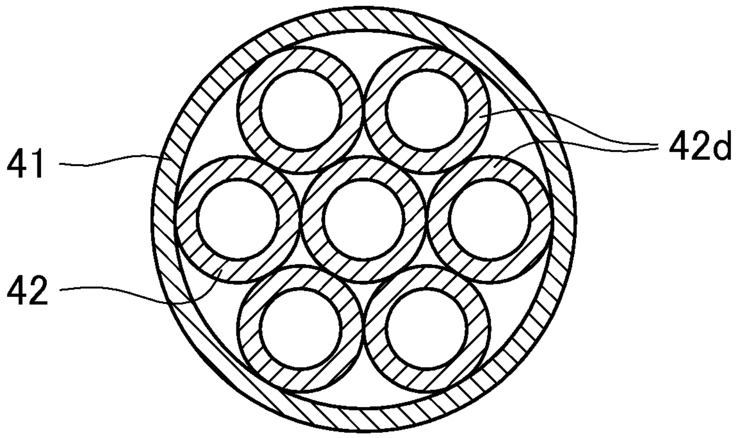
F I G. 7



F I G. 8



F I G. 9 A



F I G. 9 B

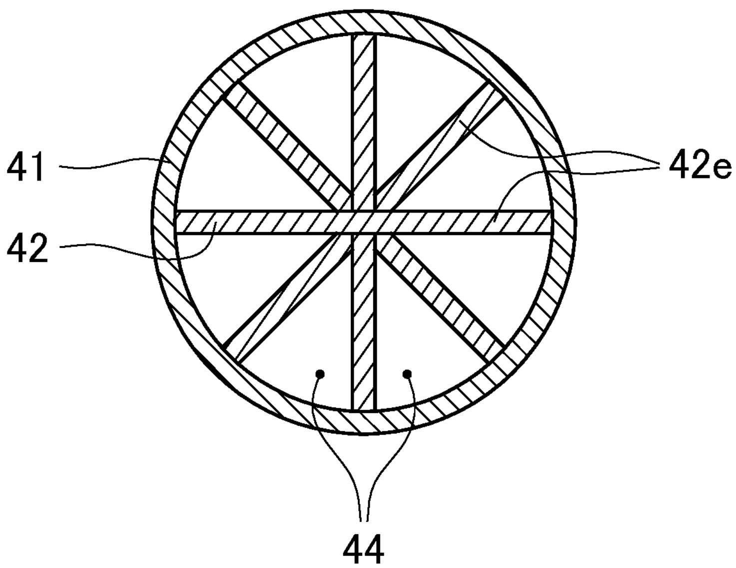


FIG. 10A

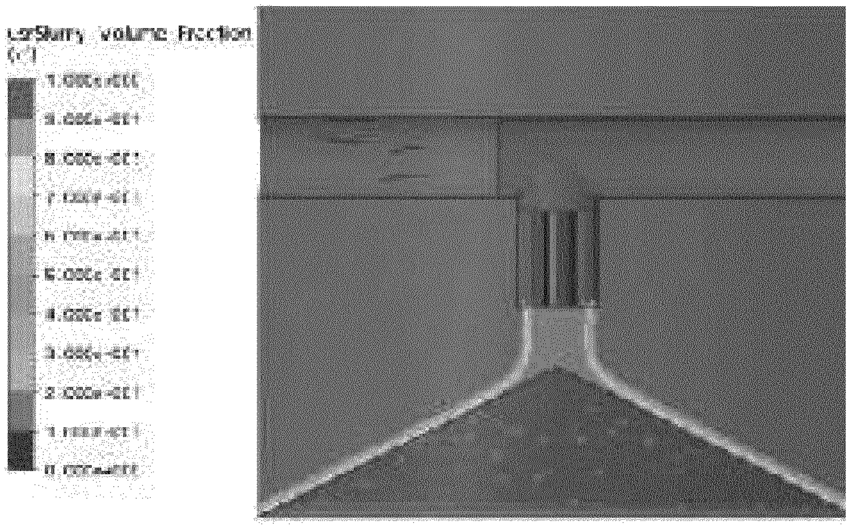
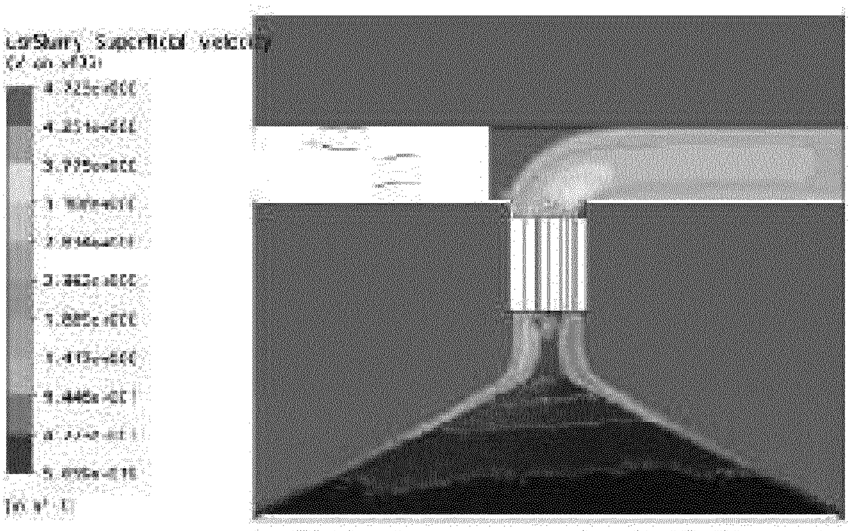
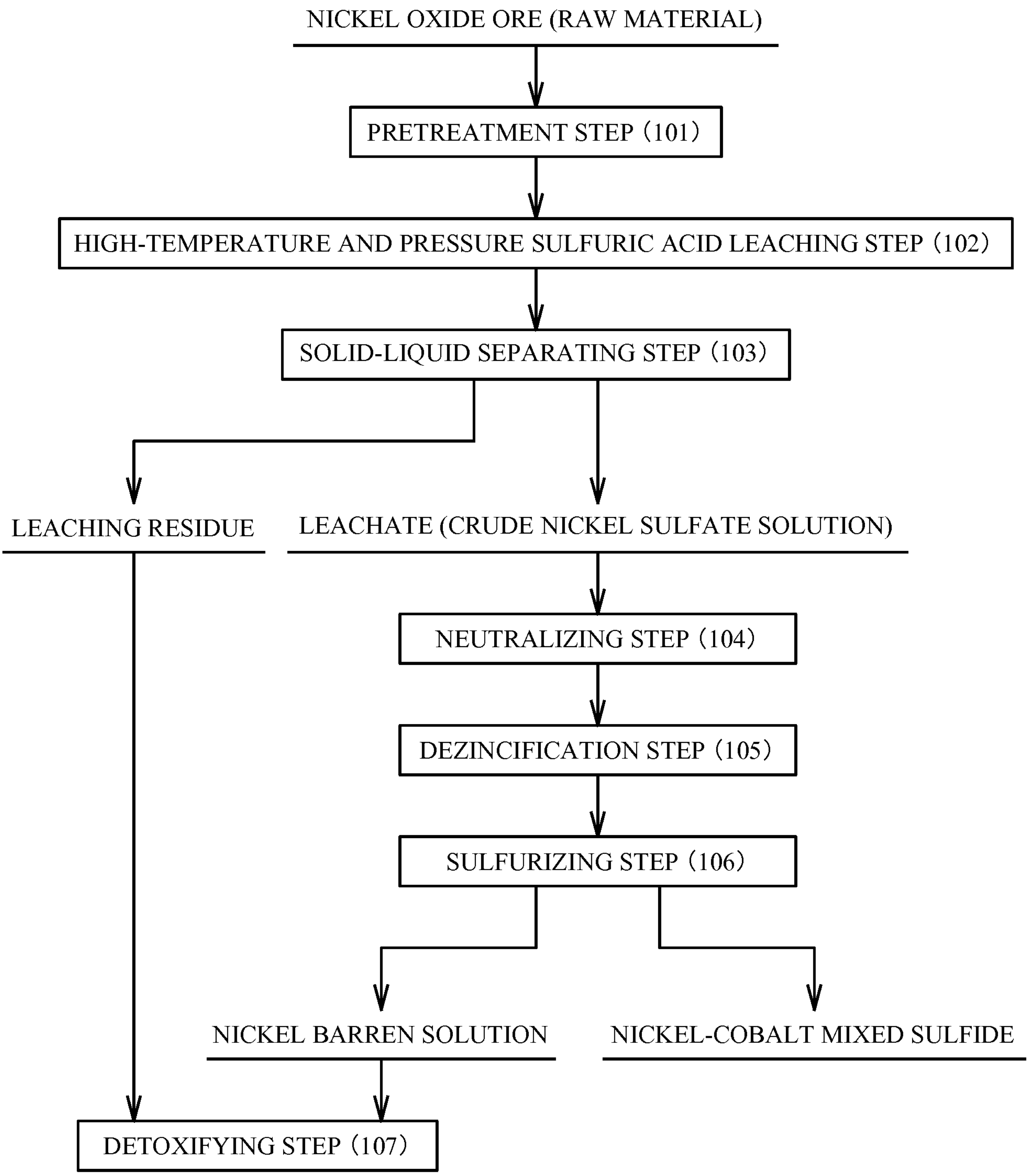


FIG. 10B



F I G. 1 1


NICKEL OXIDE ORE (RAW MATERIAL)
PRETREATMENT STEP (101)
HIGH-TEMPERATURE AND PRESSURE SULFURIC ACID LEACHING STEP (102)
SOLID-LIQUID SEPARATING STEP (103)
LEACHING RESIDUE
LEACHATE (CRUDE NICKEL SULFATE SOLUTION)
NEUTRALIZING STEP (104)
DEZINCIFICATION STEP (105)
SULFURIZING STEP (106)
NICKEL BARREN SOLUTION
NICKEL-COBALT MIXED SULFIDE
DETOXIFYING STEP (107)

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2017/010832

A. CLASSIFICATION OF SUBJECT MATTER

F28C1/06(2006.01)i, *C22B1/00*(2006.01)i, *F28C3/08*(2006.01)i, *F28C3/14*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F28C1/06, C22B1/00, F28C3/08, F28C3/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2017
Kokai Jitsuyo Shinan Koho	1971-2017	Toroku Jitsuyo Shinan Koho	1994-2017

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2010-025455 A (Sumitomo Metal Mining Co., Ltd.), 04 February 2010 (04.02.2010), paragraphs [0002] to [0036]; fig. 1 to 3 & US 2010/0019422 A1 paragraphs [0001] to [0079]; fig. 1 to 3	1,3,5,7-8 2,4,6
Y A	CD-ROM of the specification and drawings annexed to the request of Japanese Utility Model Application No. 008428/1993(Laid-open No. 060665/1994) (Inax Corp.), 23 August 1994 (23.08.1994), claim 1; fig. 1(A), (B) (Family: none)	1,3,5,7-8 2,4,6

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
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- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 May 2017 (30.05.17)	13 June 2017 (13.06.17)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2017/010832

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	CD-ROM of the specification and drawings annexed to the request of Japanese Utility Model Application No. 017845/1993(Laid-open No. 071562/1994) (Inax Corp.), 07 October 1994 (07.10.1994), claim 1; fig. 1 to 2 (Family: none)	1,3,5,7-8 2,4,6
Y A	JP 06-306901 A (Toyoda Gosei Co., Ltd.), 01 November 1994 (01.11.1994), paragraphs [0013] to [0026]; fig. 1 (Family: none)	1,3,5,7-8 2,4,6
Y A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 024848/1991(Laid-open No. 112954/1992) (Inax Corp.), 01 October 1992 (01.10.1992), claims; fig. 1 to 2 (Family: none)	1,3,5,7-8 2,4,6
A	JP 2011-141089 A (Sumitomo Heavy Industries, Ltd.), 21 July 2011 (21.07.2011), entire text; all drawings (Family: none)	1-8
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 163257/1988(Laid-open No. 084870/1990) (Toto Ltd.), 02 July 1990 (02.07.1990), entire text; all drawings (Family: none)	1-8
A	JP 50-159873 A (Anatori Porisobichi Tojiyutojiyunnikofu), 24 December 1975 (24.12.1975), entire text; all drawings (Family: none)	1-8
A	CN 204787914 U (GUANGXI STATE FARMS SUGAR INDUSTRIAL GROUP HONGHESUGAR MANUFACTURING CO., LTD.), 18 November 2015 (18.11.2015), entire text; all drawings (Family: none)	1-8

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2010025455 A **[0006]**