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(54) **DUST COLLECTOR**

(57) A precipitator comprises a gas pipe through which a treatment target gas flows from an upstream side toward a downstream side; a plurality of trapping parts provided for the gas pipe and configured to trap target particles contained in the treatment target gas; and a connection electrode connected to the plurality of trapping parts. Each of the plurality of trapping parts has: a tubular outer electrode having an internal space through which the treatment target gas passes, and an inner electrode arranged coaxially with the outer electrode in the internal space, the plurality of trapping parts is arranged in parallel in a cross section of the gas pipe, and the connection electrode is connected to the respective inner electrodes of the plurality of trapping parts and is also arranged on a further downstream side than the plurality of trapping parts.

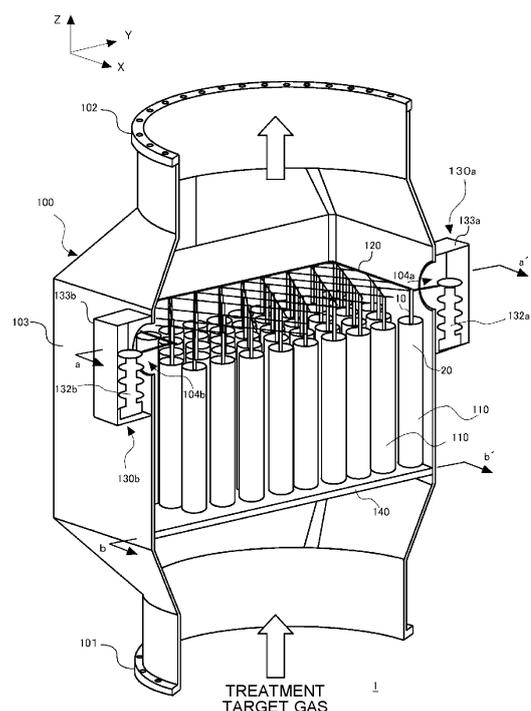


FIG. 1

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Description

BACKGROUND

1. TECHNICAL FIELD

[0001] The present invention relates to a precipitator.

2. RELATED ART

[0002] In the related art, suggested is a precipitator configured to generate corona discharge by using a coaxial cylindrical electrode structure, thereby charging particle matters in a treatment target gas and collecting dust (for example, refer to Patent Documents 1 and 2). In addition, suggested is also a precipitator having an electrode configuration where parallel flat plates having a plurality of splinter electrodes are arranged in multi layers (for example, refer to Patent Document 3).

[Patent Document 1]: Japanese Patent Application Publication No. 2012-170869

[Patent Document 2]: Japanese Patent Application Publication No. 2011-245429

[Patent Document 3]: Japanese Patent Application Publication No. 2009-166006

[TECHNICAL PROBLEM]

[0003] In the precipitator, it is preferable to stably generate the corona discharge while reducing a pressure loss at the time when the treatment target gas passes through the precipitator.

[GENERAL DISCLOSURE]

[0004] In order to solve the above-described problem, a first aspect of the present invention provides a precipitator. The precipitator may comprise a gas pipe, a plurality of trapping parts, and a connection electrode. The gas pipe may be configured so that a treatment target gas flows from an upstream side toward a downstream side. The plurality of trapping parts may be provided for the gas pipe. The plurality of trapping parts may be configured to trap target particles contained in the treatment target gas. The connection electrode may be connected to the plurality of trapping parts. Each of the plurality of trapping parts may have a tubular outer electrode. The treatment target gas may pass through an internal space of the tubular outer electrode. Each of the plurality of trapping parts may have an inner electrode. The inner electrode may be arranged coaxially with the outer electrode in the internal space. The plurality of trapping parts may be arranged in parallel in a cross section of the gas pipe. The connection electrode may be connected to the respective inner electrodes of the plurality of trapping parts. The connection electrode may be arranged on a further downstream side than the plurality of trapping parts.

[0005] The connection electrode may have a grid part. The grid part may be provided with an electrode in a grid pattern. The grid part and the respective inner electrodes may be connected.

5 **[0006]** A diameter of the electrode provided for the connection electrode in the grid pattern may be greater than a diameter of the inner electrode.

[0007] The precipitator may further comprise a sealing part. The sealing part may be configured to seal a space between the trapping parts in the plurality of trapping parts.

10 **[0008]** The sealing part may be provided at end portions on the upstream side of the plurality of trapping parts.

15 **[0009]** A distance between the connection electrode and a wall of the gas pipe may be greater than an inner diameter of the outer electrode.

[0010] The at least one outer electrode may have a length in an axial direction different from the other outer electrodes.

20 **[0011]** Among the plurality of outer electrodes, the outer electrode arranged in a centermost position on a cross section of the gas pipe may be longer than the other outer electrodes.

25 **[0012]** The respective outer electrodes may be the same in terms of positions of end portions on an upstream side.

[0013] A wall of the gas pipe may be provided with a through-hole through which the connection electrode passes. The precipitator may further comprise an accommodation part. The accommodation part may be arranged outside the gas pipe. The accommodation part may be configured to accommodate an end portion of the connection electrode passing through the through-hole. The accommodation part may be configured to support the end portion of the connection electrode. The through-hole may be arranged on a further downstream side than the plurality of trapping parts.

30 **[0014]** The precipitator may further comprise an air pressure maintaining part. The air pressure maintaining part may be configured to maintain an air pressure in the accommodation part to be higher than an air pressure in the gas pipe.

35 **[0015]** A radius of the through-hole may be greater than an inner diameter of the outer electrode.

[0016] The precipitator may comprise a first trapping part group and a second trapping part group. The first trapping part group may have the plurality of trapping parts. The plurality of trapping parts may be provided for the gas pipe. The plurality of trapping parts may be arranged in parallel in a cross section of the gas pipe. The second trapping part group may be provided on a further upstream side than the first trapping part group in the gas pipe. The second trapping part group may have the plurality of trapping parts. The plurality of compensating parts may be arranged in parallel in a cross section of the gas pipe. The precipitator may comprise a first connection electrode. The first connection electrode may be

arranged on a further downstream side than the first trapping part group. The first connection electrode may be connected to the respective inner electrodes of the first trapping part group. The precipitator may comprise a second connection electrode. The second connection electrode may be arranged between the second trapping part group and the first trapping part group. The second connection electrode may be connected to the respective inner electrodes of the second trapping part group.

[0017] The summary clause does not necessarily describe all necessary features of the embodiments of the present invention. The present invention may also be a sub-combination of the features described above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

Fig. 1 is a perspective cross-sectional view showing a configuration example of a precipitator 1 in accordance with one embodiment of the present invention. Fig. 2 shows an example of a YZ cross section of the precipitator 1.

Fig. 3 shows a configuration example of a trapping part 110.

Fig. 4 shows an example of an XY cross section of the trapping part 110 shown in Fig. 3.

Fig. 5 shows an example of an XY cross section of the precipitator 1 taken along a line a-a' in Fig. 1.

Fig. 6 shows an example of an XY cross section of the precipitator 1 taken along a line b-b' in Fig. 1.

Fig. 7 is an XY cross-sectional view showing another example of the precipitator 1.

Fig. 8 is an XY cross-sectional view showing another example of the precipitator 1.

Fig. 9 is a YZ cross-sectional view showing another example of the precipitator 1.

Fig. 10 is a YZ cross-sectional view showing an example of a precipitator 2.

Fig. 11 is a YZ cross-sectional view showing another example of the precipitator 2.

Fig. 12 is a YZ cross-sectional view showing another example of the precipitator 1.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0019] Hereinafter, the present invention will be described through embodiments of the invention, but the following embodiments do not limit the invention according to the claims. In addition, all combinations of features described in the embodiments are not necessarily essential to the solutions of the invention.

[0020] Fig. 1 is a perspective cross-sectional view showing a configuration example of a precipitator 1 in accordance with one embodiment of the present invention. The precipitator 1 is an electrostatic precipitator machine. The precipitator 1 is configured to charge and trap particles such as particle matter (PM) and black carbon

(BC) contained in a treatment target gas. The treatment target gas is an exhaust gas that is exhausted from an engine of a ship or the like, for example, but is not limited thereto.

[0021] The precipitator 1 may also be used in combination with a scrubber apparatus configured to remove dust particles by spraying a liquid to the treatment target gas. For example, after removing the particles of the treatment target gas by the precipitator 1, the particles of the treatment target gas may be further removed in the scrubber apparatus. Alternatively, after removing the particles of the treatment target gas in the scrubber apparatus, the particles of the treatment target gas may also be further removed by the precipitator 1.

[0022] The precipitator 1 comprises a gas pipe 100 through which the treatment target gas flows from an upstream side toward a downstream side, a plurality of trapping parts 110 configured to trap target particles, and a connection electrode 120 connected to the plurality of trapping parts 110. In the present example, the treatment target gas flows in a predetermined direction (the Z-axis direction, in Fig. 1).

[0023] The gas pipe 100 may have an upstream-side flange part 101 and a downstream-side flange part 102 so that the gas pipe can be attached in the middle of a pipe path for the treatment target gas. In the present example, the gas pipe 100 has a main body part 103 between the upstream-side flange part 101 and the downstream-side flange part 102.

[0024] The plurality of trapping parts 110 is each configured to trap target particles contained in the treatment target gas. The number of the plurality of trapping parts 110 to be arranged is not limited to the case shown in Fig. 1. Each of the plurality of trapping parts 110 has an inner electrode 10 and an outer electrode 20. The outer electrode 20 is a tubular metal electrode having an internal space through which the treatment target gas passes. The inner electrode 10 is a metal electrode arranged coaxially with the outer electrode 20 in the internal space. The plurality of trapping parts 110 is arranged in parallel in a cross section of the gas pipe 100. With such a configuration, it is possible to secure an amount of a treatment gas while reducing a pressure loss at the time when the treatment target gas passes through the precipitator 1. Note that, an in-line type precipitator may be configured by arranging the plurality of trapping parts 110 in parallel in the cross section of the gas pipe 100. The in-line type may mean a configuration where the trapping parts 110 are arranged in the gas pipe 100.

[0025] Unlike a parallel flat plate electrode having splinters, the trapping part 110 is configured to maintain and secure an interelectrode distance (a gap length) in the coaxial cylindrical shape. Since the inner electrode 10 and the outer electrode 20 are configured in the coaxial cylindrical shape, the inner electrode 10 and the outer electrode 20 can be manufactured by lathe processing. Therefore, it is possible to easily secure the dimension accuracy, and to accurately secure a neces-

sary interelectrode distance in a circumferential direction.

[0026] In the present example, the plurality of trapping parts 110 each having a coaxial cylindrical electrode structure is parallelized. The parallelization of the plurality of trapping parts 110 can enable implementation of a trapping capability capable of sufficiently treating the exhaust gas from an engine of an actual ship or the like.

[0027] The connection electrode 120 is formed of a conductive material such as metal. The connection electrode 120 is connected to the respective inner electrodes 10 of the plurality of trapping parts 110. By one connection electrode 120, it is possible to collectively support the inner electrodes 10 that are a plurality of high-voltage electrodes. The connection of the connection electrode 120 and the respective inner electrodes 10 may include welding, screwing, connection by a connecting member such as a joint, and a case of being integrally cast.

[0028] In the present example, the connection electrode 120 includes a part formed in a grid pattern along an XY plane. The connection electrode 120 is arranged on a further downstream side than the plurality of trapping parts 110 with respect to a flow of the treatment target gas.

[0029] A wall of the gas pipe 100 is provided with at least two through-holes 104a and 104b through which end portions of the connection electrode 120 pass. The through-hole 104a and the through-hole 104b may be provided on sidewalls of the gas pipe 100 facing each other. The through-holes 104a and 104b are arranged on a further downstream side than the plurality of trapping parts 110.

[0030] The precipitator 1 comprises at least two accommodation parts 130a and 130b. The accommodation parts 130a and 130b are arranged outside the gas pipe 100. The accommodation part 130a is configured to accommodate one end portion of the connection electrode 120 passing through the through-hole 104a and to support the one end portion of the connection electrode 120. Similarly, the accommodation part 130b is configured to accommodate the other end portion of the connection electrode 120 passing through the through-hole 104b and to support the other end portion of the connection electrode 120.

[0031] Specifically, the accommodation part 130a may have a support part 132a and an accommodation chamber 133a. The support part 132a is configured to support the end portion of the connection electrode 120. In an example, the support part 132a is an insulator. The accommodation chamber 133a is configured to accommodate the support part 132a. The accommodation chamber 133a is configured to partition the support part 132a from an external space. The support part 132a may be fixed to a side surface of the gas pipe 100 or an inner surface of the accommodation chamber 133a. The accommodation part 130b has a support part 132b and an accommodation chamber 133b. The accommodation part 130b is configured in a similar manner to the accommodation part 130a. Therefore, the repeated description

is omitted.

[0032] By the plurality of trapping parts 110, particles such as particle matter (PM) and black carbon (BC) contained in the treatment target gas are trapped. Therefore, the treatment target gas on a further downstream side than the plurality of trapping parts 110 less contains particles such as particle matter (PM) and black carbon (BC) than the treatment target gas on a further upstream side than the plurality of trapping parts 110. The connection electrode 120 is arranged on a further downstream side than the plurality of trapping parts 110 with respect to the flow of the treatment target gas. According to this configuration, it is possible to reduce defacement of the connection electrode 120. When the conductive PM adheres to the connection electrode 120, the connection electrode 120 becomes substantially thick and inequality, which is a feature of corona discharge, cannot be secured, so that spark discharge may frequently occur. In addition, even if the PM has low conductivity, when the PM adheres or deposits on the connection electrode 120, since the PM is a dielectric, the deposited PM is polarized to cause discharge called back discharge, so that sparks may frequently occur. According to the present example, defacement of the connection electrode 120 due to the PM is reduced, so that it is possible to stably generate corona discharge while avoiding the spark discharge.

[0033] Further, the through-holes 104a and 104b are arranged on the further downstream side than the plurality of trapping parts 110, so that defacement of insides of the accommodation parts 130a and 130b can be reduced. This makes it possible to prevent insulating properties of the support parts 132a and 132b from being damaged due to defacement of the support parts 132a and 132b as much as possible. Therefore, it is possible to prevent spark discharge at the support parts 132a and 132b.

[0034] The precipitator 1 may further comprise a sealing part 140 configured to seal a space between the adjacent trapping parts in the plurality of trapping parts 110. The sealing part 140 is configured to prevent the treatment target gas from escaping toward a downstream side through a gap between the adjacent trapping parts.

[0035] When a cross-sectional area of an internal space of the outer electrode 20 of one trapping part 110 arranged in the main body part 103 is denoted as S and the number of the plurality of trapping parts 110 arranged in parallel in a cross section of the gas pipe 100 is denoted as n, a sum ($S \times n$) of the cross-sectional areas S of the n internal spaces may be configured to be equal to or greater than a cross-sectional area S_g of an internal space of each pipe connected to the upstream-side flange part 101 and the downstream-side flange part 102, respectively. When a cross-sectional area of an internal space of the main body part 103 is denoted as S_a and an area sealed by the sealing part 140 in the XY plane is denoted as S_r , $S_a - S_r$ may be configured to be equal to or greater than S_g . In this case, the cross-sectional area S_a of the main body part 103 is greater than the cross-

sectional area S_g of each pipe connected to the upstream-side flange part 101 and the downstream-side flange part 102, respectively. This makes it possible to reduce a pressure loss as the time when the treatment target gas passes through insides of the trapping parts 110. The respective cross-sectional areas S , S_g and S_a are cross-sectional areas of respective parts on a plane cut perpendicular to a longitudinal direction (a flow direction of the treatment target gas).

[0036] Fig. 2 schematically shows an example of a YZ cross section of the precipitator 1. Fig. 2 shows a YZ cross section passing through the support parts 132a and 132b in Fig. 1. However, for convenience of description, the number of the plurality of trapping parts 110 is shown smaller than the configuration shown in Fig. 1.

[0037] The plurality of trapping parts 110-1, 110-2, 110-3 and 110-4 (collectively referred to as the trapping parts 110) may be fixed to the common plate-shaped sealing part 140 by welding or the like. An edge portion of the sealing part 140 may be fixed to an inner wall of the gas pipe 100 constituting a flue by welding or the like. That is, the plurality of trapping parts 110 may be fixed inside of the gas pipe 100 through the common sealing part 140. The sealing part 140 is provided at end portions on an upstream side of the plurality of trapping parts 110. This makes it possible to prevent the treatment target gas from entering spaces among the plurality of trapping parts 110. However, the sealing part 140 is not limited thereto, and may also be provided at end portions on a downstream side of the plurality of trapping parts 110 or may also be respectively provided at the respective end portions on the upstream side and on the downstream side of the plurality of trapping parts 110.

[0038] The precipitator 1 of the present example comprises an air pressure maintaining part 150. The air pressure maintaining part 150 is configured to maintain an air pressure in the accommodation chamber 133a of the accommodation part 130a to be higher than an air pressure in the gas pipe 100. The air pressure maintaining part 150 may also be configured to introduce an inert gas such as nitrogen into the accommodation part 130a or to introduce air. This makes it possible to suppress inflow of the treatment target gas into the accommodation chamber 133a through the through-hole 104a. Similarly, the air pressure maintaining part 150 is configured to maintain an air pressure in the accommodation chamber 133b of the accommodation part 130b to be higher than the air pressure in the gas pipe 100. This makes it possible to suppress inflow of the treatment target gas into the accommodation chamber 133b through the through-hole 104b. According to the air pressure maintaining part 150, it is possible to suppress the particles in the treatment target gas from adhering to the support parts 132 and 132b and the like, which are insulators and the like, and to prevent undesirable discharge from occurring at the insulators and the like.

[0039] The precipitator 1 may be provided with a voltage applying part 152 configured to apply a voltage to

the connection electrode 120. The voltage applied by the voltage applying part 152 is applied to the inner electrodes 10 of the respective trapping parts 110 through the connection electrode 120. In addition, the connection electrode 120 is configured to mechanically fix the inner electrodes 10. In the present example, the inner electrode 10 extends in one direction (in the present example, a vertical direction). One ends (upper ends) of the inner electrodes 10 are fixed to a grid part of the connection electrode 120 where an electrode is provided in a grid pattern. In other words, in the present example, the respective inner electrodes 10 and the connection electrode 120 may constitute a cantilever beam where one ends of the inner electrodes 10 are fixed ends and the other ends are free ends. By adopting the cantilever beam structure, it becomes easy to secure dust collecting performance corresponding to characteristics and operating load situations of an engine to which the precipitator 1 is applied.

[0040] A diameter $W2$ of the electrode provided for the connection electrode 120 in the grid pattern is greater than a diameter $W1$ of the inner electrode 10. This prevents the connection electrode 120 from being distorted or bent. In the present example, in a case where a cross-sectional shape of the connection electrode 120 is not circular, the diameter $W2$ of the electrode may be a thickness in the Z-axis direction. Increasing the thickness of the connection electrode 120 of the present example prevents the connection electrode 120 from being distorted or bent. Thereby, even when the connection electrode 120 suspends the plurality of inner electrodes 10, angles at which the inner electrodes 10 are suspended do not change, so that the inner electrodes 10 and the outer electrodes 20 can be maintained parallel. In the present example, since a gap between the inner electrode 10 and the outer electrode 20 can be maintained at a predetermined distance, the corona discharge can be stably generated.

[0041] A radius $R1$ of each of the through-holes 104a and 104b may be greater than an inner diameter Rb of the cylindrical outer electrode 20. This makes it possible to prevent discharge between the gas pipe 100 having the through-holes 104a and 104b and the connection electrode 120.

[0042] Each of the trapping parts 110 may have a trapping electrode 30, in addition to the inner electrode 10 and the outer electrode 20. Subsequently, the trapping part 110 is described.

[0043] Fig. 3 shows a configuration example of the trapping part 110. In Fig. 3, the outer electrode 20 has a rod shape having a length in a predetermined direction (the Z-axis direction, in Fig. 3), and an internal space 40 is provided inside the rod shape. In the present example, the outer electrode 20 has a cylindrical shape.

[0044] The internal space 40 connects to an external space at both ends in the Z-axis direction of the outer electrode 20. At an end portion in the Z-axis direction, the treatment target gas is introduced into the internal

space 40. In the present specification, the longitudinal direction of the outer electrode 20 is assumed to be the Z-axis direction, and two orthogonal axes perpendicular to the Z-axis are assumed to be the X-axis and the Y-axis. In the present example, the outer electrode 20 is configured to surround the internal space 40 with a plate-shaped metal electrode.

[0045] The treatment target gas passes through the internal space 40. In the present example, the treatment target gas passes through the internal space 40 along the Z-axis direction. The trapping part 110 is configured to trap particles contained in the passing treatment target gas.

[0046] The inner electrode 10 is a metal electrode arranged coaxially with the outer electrode 20 in the internal space 40. That is, the inner electrode 10 is arranged at a center of the internal space 40 on the XY plane perpendicular to the Z-axis direction. The center of the internal space 40 may be a geometric center of gravity of the internal space 40 on the XY plane. In a case where the internal space 40 on the XY plane has a circular shape, the center of the internal space 40 is a center of the circle. The inner electrode 10 has a linear shape parallel to the Z-axis direction. The shape of the inner electrode 10 on the XY plane is preferably circular. The inner electrode 10 may or may not have a cavity therein. A distance between the inner electrode 10 and the outer electrode 20 on the XY plane is uniform over the entire Z-axis direction.

[0047] A reference potential is applied to the outer electrode 20. The reference potential is, for example, a ground potential. A predetermined high potential higher than the potential of the outer electrode 20 is applied to the inner electrode 10. By applying the predetermined potentials to the respective electrodes, the corona discharge is generated in the internal space 40 between the inner electrode 10 and the outer electrode 20. This makes it possible to charge the particles contained in the treatment target gas passing through the internal space 40.

[0048] Each of the trapping parts 110 is configured to trap the charged particles in a predetermined region by using Coulomb force or the like. The trapping part 110 of the present example is configured to trap the charged particles in an outer region of the outer electrode 20. The trapping part 110 of the present example further has a trapping electrode 30. The trapping electrode 30 is a tubular metal electrode arranged to surround the outer electrode 20 and having a length in the Z-axis direction. In the Z-axis direction, the trapping electrode 30 and the outer electrode 20 may have the same lengths. A potential lower than the inner electrode 10 is applied to the trapping electrode 30. The same potential as the outer electrode 20 may be applied to the trapping electrode 30. For example, both the trapping electrode 30 and the outer electrode 20 may be grounded. In this case, the trapping electrode 30 and the outer electrode 20 constitute a ground electrode.

[0049] A trapping space 50 is provided between the

trapping electrode 30 and the outer electrode 20. In addition, the plate-shaped metal electrode of the outer electrode 20 is provided with a plurality of outer electrode through-holes 22. The outer electrode through-holes 22 are formed to connect the internal space 40 and the trapping space 50 each other.

[0050] The charged particles present in the internal space 40 are moved in a direction from the inner electrode 10 toward the outer electrode 20 by Coulomb force and ion wind generated by the corona discharge. The charged particles pass through the outer electrode through-holes 22 and are trapped in the trapping space 50. Note that, the arrangement of the trapping space 50 is not limited to the present example. The trapping space 50 may also be arranged downstream of the outer electrode 20. That is, the charged particles contained in the treatment target gas after passing through the internal space 40 may also be trapped downstream of the outer electrode 20.

[0051] According to the trapping part 110 of the present example, the electrode is not provided with a plurality of protrusions, and the columnar inner electrode 10 and the cylindrical outer electrode 20 are coaxially arranged. For this reason, it is possible to suppress concentration of the electric field on a specific place and to suppress the spark discharge. In addition, the treatment target gas may be at high temperatures in the trapping part 110. For example, the treatment target gas at up to 400°C may be introduced into the trapping part 110 for a ship. In this way, even when the temperature change becomes large, it is possible to suppress the distance between the inner electrode 10 and the outer electrode 20 from being non-uniform, because the trapping part 110 has the cylindrical coaxial structure. For this reason, it is possible to suppress the spark discharge.

[0052] Fig. 4 shows an example of an XY cross section of the trapping part 110. In Fig. 4, the inner electrode 10, the outer electrode 20 and the trapping electrode 30 are diagonally hatched. In the other drawings, the hatching for the electrodes may be omitted.

[0053] The inner electrode 10 is arranged at a center 12 of the internal space 40 on the XY plane. That is, on the XY plane, the center 12 of the internal space 40 overlaps the inner electrode 10. On the XY plane, a center of the inner electrode 10 preferably coincides with the center 12 of the internal space 40.

[0054] As shown in Fig. 4, an outer diameter of the inner electrode 10 is denoted as Ra. The outer diameter of the inner electrode 10 is a radius of the inner electrode 10 on the XY plane. That is, the outer diameter of the inner electrode 10 is a distance between the center of the inner electrode 10 and an outer circumferential end 14 of the inner electrode 10. The outer circumferential end 14 of the inner electrode 10 of the present example is a circle along an outer circumference of the inner electrode 10.

[0055] As shown in Fig. 4, an inner diameter of the outer electrode 20 is denoted as Rb. The inner diameter

of the outer electrode 20 is a radius of an inner wall 24 of the outer electrode 20 on the XY plane. That is, the inner diameter of the outer electrode 20 is a distance between the center 12 and the inner wall 24 of the outer electrode 20. The outer electrode 20 of the present example has the inner wall 24 in contact with the internal space 40, and an outer wall 26 in contact with the trapping space 50. In addition, the outer electrode through-holes 22 of the outer electrode 20 penetrate through the outer electrode 20 from the inner wall 24 to the outer wall 26.

[0056] A ratio R_a/R_b of the outer diameter R_a of the inner electrode 10 and the inner diameter R_b of the outer electrode 20 is smaller than $1/e$. Note that, e is the base of the natural logarithm, and $e=2.71828$. This makes it possible to stably form the corona discharge in the internal space 40.

[0057] As for the tubular electrode coaxially arranged, it is known that the insulation efficiency is highest when the above-described ratio R_a/R_b is the same as $1/e$ (for example, refer to the below literature. "High voltage engineering", Asakura Publishing Co. Ltd. KOUNO Teruya, pp. 28-29). For example, for a coaxial cable and the like, since it is preferable to increase insulating properties of an inner wiring and an outer shield, it is preferable to design the ratio R_a/R_b to be the same as $1/e$.

[0058] When the ratio R_a/R_b is the same as $1/e$, an electric field intensity distribution is likely to be uniform from the inner electrode 10 to the outer electrode 20. Such a state is referred to as a quasi-equal system. In the quasi-equal system, a dielectric breakdown is less likely to occur, but when the dielectric breakdown occurs, the spark discharge occurs immediately and the corona discharge cannot be generated.

[0059] If the ratio R_a/R_b is made smaller than $1/e$, the electric field is concentrated in the vicinity of the inner electrode 10 and the electric field intensity distribution from the inner electrode 10 to the outer electrode 20 becomes non-uniform. Such a state is referred to as an unequal system. In the unequal system, since the electric field is concentrated in the vicinity of the inner electrode 10, the corona discharge is likely to be generated.

[0060] In the trapping part 110 of the present example, on the XY plane, it becomes easy to uniformly generate the corona discharge in the entire internal space 40 at 360 degrees around the inner electrode 10. Further, also in the Z-axis direction, it becomes easy to uniformly generate the corona discharge in the entire internal space 40. This makes it possible to effectively charge the particles contained in the treatment target gas passing through the internal space 40. On the other hand, in a method of providing protrusions on the flat plate electrode and causing corona discharge, the electric field intensity changes according to a distance from the protrusions. For this reason, in some cases, it is difficult to charge particles passing through a region spaced from the protrusions, such as a center between the two protrusions.

[0061] The smaller the ratio R_a/R_b is than $1/e$, the more stably the corona discharge can be generated. The ratio

R_a/R_b may be smaller than $1/(2e)$. The ratio R_a/R_b may be smaller than $1/(5e)$ and may also be smaller than $1/(10e)$.

[0062] For example, the outer diameter R_a of the inner electrode 10 is equal to or greater than 1mm and equal to or smaller than 10mm. The outer diameter R_a of the inner electrode 10 may also be equal to or smaller than 5mm. The inner diameter R_b of the outer electrode 20 is equal to or greater than 10mm and equal to or smaller than 100mm. The inner diameter R_b of the outer electrode 20 may be equal to or greater than 50mm.

[0063] In addition, a distance d between the outer circumferential end 14 of the inner electrode 10 and the inner wall 24 of the outer electrode 20 may be equal to or smaller than 40mm. The distance d corresponds to a difference R_b-R_a between the inner diameter R_b and the outer diameter R_a . When the distance d becomes too large, the electric field in the vicinity of the outer electrode 20 becomes weak, so that it is difficult to charge the particles passing through the vicinity of the outer electrode 20. By setting the distance d to 40mm or smaller, it is possible to secure the sufficient electric field in the entire internal space 40. For this reason, it becomes easy to charge all the particles passing through the internal space 40.

[0064] The trapping part 110 of the present example further has a combustion part 60 configured to combust the charged particles, in addition to the configuration described in Fig. 3. The combustion part 60 is, for example, a heater. The combustion part 60 may be provided on an inner wall surface of the trapping electrode 30. The inner wall surface of the trapping electrode 30 is a wall surface, which faces the outer electrode 20, of wall surfaces of the trapping electrode 30. In another example, the combustion part 60 may also have an electrode configured to generate microwaves in the trapping space 50. The combustion part 60 may be configured to control wavelengths of the microwaves so that the microwaves in the trapping space 50 become standing waves. The generation of the standing waves of the microwaves concentrates the energy on peak portions of the standing waves, making it easier to combust the particles. By combusting the charged particles, it is possible to suppress the trapping space 50 from being filled with the charged particles.

[0065] Fig. 5 schematically shows an example of an XY cross section of the precipitator 1 taken along a line a-a' in Fig. 1. The connection electrode 120 of the present example has a plurality of extension portions 121a and 121b and a grid part 122. The extension portion 121a is an electrode extending from one side of the grid part 122 toward the through-hole 104a. Similarly, the extension portion 121b is an electrode extending from another side facing the one side of the grid part 122 toward the through-hole 104a. The extension portions 121a and 121b may be provided in facing positions with the grid part 122 interposed therebetween.

[0066] The grid part 122 is a part where an electrode

is provided in a grid pattern. In the present example, the grid part 122 includes a frame portion 123 constituting an outline of the grid part 122, a plurality of first extension portions 124 (124-1, 124-2, 124-3, 124-4) extending in one direction in a region surrounded by the frame portion 123, and a plurality of second extension portions 125 extending in another direction in the region surrounded by the frame portion 123. In addition, the grid part 122 may have a linear portion extending in a linear shape between the extension portions 121a and 121b. However, the pattern of the grid part 122 may be a pattern where the grid part 122 is connected to the inner electrodes 10 of the respective trapping parts 110 and the grid part 122 can fix the positions of the inner electrodes 10, and is not limited to the case of Fig. 5.

[0067] A diameter W3 of the electrode provided for the connection electrode 120 in the grid pattern is greater than the diameter W1 of the inner electrode 10. Note that, the diameter W3 of the electrode may be an electrode width in a width direction in the XY plane. As shown in Fig. 2, the electrode thickness W2 of the electrode in the Z-axis direction is also greater than the diameter W1 of the inner electrode 10. With such a configuration, it is possible to prevent the connection electrode 120 from being distorted or bent. Therefore, the position and the extending angle of each inner electrode 10 are fixed by the connection electrode 120. This maintains the inter-electrode distance between the inner electrode 10 and the outer electrode 20, making it possible to generate the stable corona discharge.

[0068] A distance Lc between the connection electrode 120 and the wall of the gas pipe 100 may be greater than the inner diameter (radius) Rb of the outer electrode 20. In addition, the radius R1 of each of the through-holes 104a and 104b is greater than the inner diameter (radius) Rb of the outer electrode 20. With such a configuration, it is possible to prevent discharge between the gas pipe 100 and the connection electrode 120.

[0069] Fig. 6 schematically shows an example of an XY cross section of the precipitator 1 taken along a line b-b' in Fig. 1. In Fig. 6, the inner electrode 10 and the sealing part 140 are diagonally hatched. In the other drawings, the hatching for the electrode may be omitted.

[0070] As shown in Fig. 6, the sealing part 140 has a flat plate shape. The sealing part 140 is provided with a plurality of openings 142 corresponding to positions to which the respective trapping parts 110 are attached. An end edge of the opening 142 and the outer electrode 20 may be welded. Thereby, the opening 142 and the outer electrode 20 communicate. An end portion of the trapping electrode 30 may be welded to the XY plane of the sealing part 140. Thereby, the sealing part 140 is configured to cover between the end portion of the trapping electrode 30 and the end portion of the outer electrode 20. Therefore, it is possible to prevent the treatment target gas from flowing into the trapping space 50 (Fig. 4) between the trapping electrode 30 and the outer electrode 20.

[0071] An end edge of the sealing part 140 can be

bonded to the inner surface of the gas pipe 100 by welding or the like. Therefore, it is possible to securely fix the position of the trapping electrode 30 and the position of the outer electrode 20 via the sealing part 140.

5 **[0072]** Fig. 7 is an XY cross-sectional view showing another example of the precipitator 1. In the present example, each of the trapping parts 110 has the inner electrode 10 and the outer electrode 20 and does not have the trapping electrode 30 and the combustion part 60.

10 **[0073]** The precipitator 1 shown in Fig. 7 comprises a trapping electrode 30 arranged to surround a plurality of outer electrodes 20 arranged in parallel. That is, the plurality of outer electrodes 20 is arranged in a region surrounded by the one trapping electrode 30. A shape and a size of an outer edge of the trapping electrode 30 may be substantially the same as a shape and a size of the inner surface of the gas pipe 100. The trapping part 110 may also have a combustion part 60 arranged to surround the plurality of outer electrodes 20 arranged in parallel.

20 The combustion part 60 may be a heater provided on an inner wall surface of the trapping electrode 30. According to the present example, the trapping electrode 30 and the combustion part 60 of the plurality of trapping parts 110 can be commonly used.

25 **[0074]** As shown in Fig. 7, the connection electrode 120 has a grid pattern different from the case shown in Fig. 5. According to the configuration shown in Fig. 7, one electrode is connected to one inner electrode 10 so as not to hinder the flow of the treatment target gas. However, the present invention is not limited to this case, and as shown in Fig. 5, the grid pattern where the plurality of electrodes is connected to one inner electrode 10 may also be adopted.

30 **[0075]** The respective outer electrodes 20 are provided with the outer electrode through-holes 22 shown in Fig. 4 and the like. The respective outer electrodes 20 may be welded to the sealing part 140. In addition, the respective outer electrodes 20 may also be welded each other. A charging material may be filled between the outer electrodes 20 so that a gap is not formed between the outer electrodes 20. The filling material may be a conductive material such as metal or may also be an insulating material such as resin.

35 **[0076]** Fig. 8 is an XY cross-sectional view showing another example of the precipitator 1. As for the precipitator 1 shown in Figs. 5 and 7, the case where the sidewalls of the gas pipe 100 are provided with the two through-holes 104a and 104b is shown. In the example shown in Fig. 8, the sidewalls of the gas pipe 100 are provided with four through-holes 104a, 104b, 104c and 104d. The through-hole 104a and the through-hole 104b may be provided on a pair of sidewalls of the gas pipe 100 facing each other in a first direction (Y-axis direction). The through-hole 104c and the through-hole 104d may be provided on a pair of sidewalls of the gas pipe 100 facing each other in a second direction (X-axis direction).

40 **[0077]** The precipitator 1 comprises four accommodation parts 130a, 130b, 130c and 130d. The accommoda-

tion parts 130a, 130b, 130c and 130d are arranged outside the gas pipe 100. The accommodation parts 130a and 130b face each other in the Y-axis direction. The accommodation parts 130c and 130d face each other in the X-axis direction. The configurations of the respective accommodation parts 130a, 130b, 130c and 130d are similar to the respective accommodation parts 130a and 130b shown in Fig. 5.

[0078] The connection electrode 120 shown in Fig. 8 has a grid part 122 and a plurality of extension portions 121a, 121b, 121c and 121d extending from the grid part 122. The extension portions 121a and 121b extend along the Y-axis direction, respectively. The extension portions 121c and 121d extend along the X-axis direction, respectively. The accommodation part 130c is configured to accommodate and support an end portion of the extension portion 121c passing through the through-hole 104c. Similarly, the accommodation part 130d is configured to accommodate and support an end portion of the extension portion 121d passing through the through-hole 104d. According to the present example, since the connection electrode 120 is fixed in the first direction and in the second direction different from the first direction, the distortion and bending of the connection electrode 120 can be further reduced. In particular, it is possible to prevent distortion of the connection electrode 120 about the Y-axis as a central axis.

[0079] Fig. 9 is a YZ cross-sectional view schematically showing another example of the precipitator 1. In the present example, at least one outer electrode of a plurality of outer electrodes 20 has a length in an axis direction different from the other outer electrodes. The axis direction may be a longitudinal direction of the outer electrode 20 or may be a flow direction of the treatment target gas. In the present example, the axis direction is the Z-axis direction. Among the plurality of outer electrodes 20-1 to 20-5, the outer electrode 20-3 arranged in a centermost position on the XY cross section of the gas pipe 100 is longer than the other outer electrodes.

[0080] In the present example, a length L1 of the outer electrode 20-3 is longer than respective lengths L2 of the outer electrodes 20-2 and 20-4, and the respective lengths L2 of the outer electrodes 20-2 and 20-4 are longer than respective lengths L3 of the outer electrodes 20-1 and 20-5. That is, in the present example, the length L1 of the outer electrode 20-3 arranged in the centermost position on the XY cross section of the gas pipe 100 is longest, and the lengths of the outer electrodes 20 become shorter from the center toward the outer side.

[0081] According to the present example, since the treatment target gas is likely to flow at the center of the gas pipe 100, the length L1 of the outer electrode 20-3 is made long, making it possible to increase the dust collecting force. However, the precipitator 1 of the present example is not limited to this case, and at a place after the gas pipe is bent, the outer electrode 20-1 or 20-5 at an end on the XY cross section of the gas pipe 100 may also be made long.

[0082] In the present example, the respective outer electrodes 20-1 to 20-5 are the same in terms of positions of end portions on the upstream side. If there is an unevenness on a side where the treatment target gas flows in, a flow path may change. Therefore, by aligning surfaces on the side where the treatment target gas flows in, the treatment target gas is likely to equally enter the plurality of trapping parts 110.

[0083] Fig. 10 is a YZ cross-sectional view schematically showing an example of a precipitator 2. The precipitator 2 of the present example comprises a first unit 4 and a second unit 5. The first unit 4 and the second unit 5 correspond to the precipitator 1 described in Figs. 1 to 9, respectively.

[0084] The precipitator 2 comprises a first trapping part group 112. The first trapping part group 112 has a plurality of trapping parts 110-1, 110-2, 110-3, 110-4 and 110-5 (collectively referred to as the trapping parts 110). The plurality of trapping parts 110 is provided inside the gas pipe 100. The plurality of trapping parts 110 is arranged in parallel in the XY cross section of the gas pipe 100.

[0085] The precipitator 2 comprises a second trapping part group 212. The second trapping part group 212 is provided on a further upstream side than the first trapping part group 112 in the gas pipe 100. The second trapping part group 212 has a plurality of trapping parts 210-1, 210-2, 210-3, 210-4 and 210-5 (collectively referred to as the trapping parts 210). The plurality of trapping parts 210 is provided inside the gas pipe 100. The plurality of trapping parts 210 is arranged in parallel in the XY cross section of the gas pipe 100.

[0086] The precipitator 2 comprises a first connection electrode 120 and a second connection electrode 220. The first connection electrode 120 is arranged on a further downstream side than the first trapping part group 112. The first connection electrode 120 is connected to the respective inner electrodes 10 of the first trapping part group 112. The second connection electrode 220 is arranged between the second trapping part group 212 and the first trapping part group 112. The second connection electrode 220 is connected to the respective inner electrodes 10 of the second trapping part group 212.

[0087] The precipitator 2 may comprise first accommodation parts 130a and 130b and second accommodation parts 230a and 230b. The second accommodation part 230a is configured to accommodate one end portion of the connection electrode 220 passing through a through-hole 204a and to support the one end portion of the connection electrode 220. Similarly, the second accommodation part 230b is configured to accommodate the other end portion of the connection electrode 220 passing through a through-hole 204b and to support the other end portion of the connection electrode 220. The configurations of the first accommodation parts 130a and 130b are similar to the configurations shown in Fig. 2. Therefore, the repeated description is omitted.

[0088] According to the configuration of Fig. 10, the plurality of trapping parts 110 of the first trapping part

group 112 and the plurality of trapping parts 210 of the second trapping part group 212 are respectively separated. Specifically, the respective outer electrodes 20 of the first trapping part group 112 and the respective outer electrodes 20 of the second trapping part group 212 are separated. In addition, the respective trapping electrodes 30 of the first trapping part group 112 and the respective trapping electrodes 30 of the second trapping part group 212 are also separated.

[0089] If the length of the trapping part 110 in the longitudinal direction becomes too long, it is difficult to maintain the interelectrode distance between the inner electrode 10 and the outer electrode 20. In this respect, the trapping part is divided into the trapping part 110 and the trapping part 210 and arranged in a plurality of stages, like the present embodiment, so that the length of the inner electrode 10 per one can be shortened. In addition, the length of the outer electrode 20 per one and the length of the trapping electrode 30 per one can be shortened. Therefore, while avoiding the spark discharge by maintaining the interelectrode distance between the inner electrode 10 and the outer electrode 20, it is possible to enhance the trapping capability, similar to the case where the length of the trapping part in the longitudinal direction is lengthened.

[0090] As described above, the respective inner electrodes 10 of the first trapping part group 112 and the respective inner electrodes 10 of the second trapping part group 212 may not be mechanically coupled. However, the present invention is not limited to this case, and the respective inner electrodes 10 of the first trapping part group 112 and the respective inner electrodes 10 of the second trapping part group 212 may also be mechanically coupled. Also in this case, the respective outer electrodes 20 of the first trapping part group 112 and the respective outer electrodes 20 of the second trapping part group 212 may be separated. That is, in the trapping parts 110 of the first trapping part group 112 and the trapping parts 210 of the second trapping part group 212, at least one of the inner electrodes 10 and the outer electrodes 20 may be separated.

[0091] Fig. 11 is a YZ cross-sectional view schematically showing another example of the precipitator 2. In the present example, a density of the grid (mesh) of the second connection electrode 220 positioned on a further upstream side than the first connection electrode 120 is sparser than a density of the grid of the first connection electrode 120. In addition, the inner diameters (radii) R_b of the outer electrodes 20 of the second trapping part group 212 positioned on a further upstream side than the first trapping part group 112 are greater than the inner diameters (radii) R_b of the outer electrodes 20 of the first trapping part group 112. These features make it possible to reduce contamination of the upstream-side unit to which the particles such as particle matter (PM) and black carbon (BC) are likely to adhere.

[0092] Fig. 12 is a YZ cross-sectional view schematically showing another example of the precipitator 1. In

the present example, the longitudinal directions of the respective inner electrodes 10-1, 10-2, 10-3 and 10-4 of the plurality of trapping parts 110-1, 110-2, 110-3 and 110-4 are directions different from the vertical direction.

In order to secure the interelectrode distance (gap) between the inner electrode 10 and the outer electrode 20, the inner electrode 10 and the outer electrode 20 are preferably arranged to extend in the vertical direction. By arranging the inner electrode 10 to extend in the vertical direction, it is possible to make it difficult for deformation due to an own weight of the inner electrode 10 and resulting deviation of the interelectrode distance to occur. However, the precipitator 1 of the present invention is not limited to this case.

[0093] In the example shown in Fig. 12, the Z-axis direction is the vertical direction. In an example, the respective inner electrodes 10-1, 10-2, 10-3 and 10-4 of the plurality of trapping parts 110 extend in the Y-axis direction orthogonal to the vertical direction. In the present example, the gas pipe 100 extends in the Y-axis direction. Therefore, the treatment target gas flows along the Y-axis direction.

[0094] The precipitator 1 of the present example comprises a first connection electrode 120-1 and a second connection electrode 120-2. The first connection electrode 120-1 is connected to one ends of the respective inner electrodes 10-1, 10-2, 10-3 and 10-4 of the plurality of trapping parts 110 by welding or the like. The second connection electrode 120-2 is connected to the other ends of the respective inner electrodes 10-1, 10-2, 10-3 and 10-4 by welding or the like. In the present example, a double supported beam where both one end and the other end of the inner electrode 10-1 are fixed ends is constituted. This makes it possible to prevent the inner electrode 10 from being bent due to the gravity in the vertical direction, and to stably generate the corona discharge. However, the present invention is not limited to this case, and the second connection electrode 120-2 may be omitted and a cantilever beam structure may also be adopted, depending on the rigidity or length of the inner electrode 10. In this case, the first connection electrode 120-1 becomes a connection electrode that is connected to the respective inner electrodes 10 of the plurality of trapping parts 110 and is arranged on a further downstream side than the plurality of trapping parts 110.

[0095] In the present example, the first connection electrode 120-1 is arranged on a further downstream side than the plurality of trapping parts 110-1, 110-2, 110-3 and 110-4 (collectively referred to as the trapping parts 110). The second connection electrode 120-2 is arranged on a further upstream side than the plurality of trapping parts 110. The precipitator 1 comprises at least four accommodation parts 130-1, 130-2, 130-3 and 130-4. The accommodation parts 130-1 and 130-2 are configured to function as a pair of accommodation parts. The accommodation part 130-1 is configured to accommodate one end portion of the connection electrode 120-1 passing through a through-hole 104-1 and to support the one end

portion of the connection electrode 120-1. Similarly, the accommodation part 130-2 is configured to accommodate the other end portion of the connection electrode 120-1 passing through a through-hole 104-2 and to support the other end portion of the connection electrode 120-1. The through-hole 104-1 and the through-hole 104-2 are similar to the above-described through-holes 104a and 104b. In addition, the accommodation part 130-1 has a support part 132-1 and an accommodation chamber 133-1, and the accommodation part 130-2 has a support part 132-2 and an accommodation chamber 133-2. The configurations of the support parts 132-1 and 132-2 and the accommodation chambers 133-1 and 133-2 are similar to the configurations of the support parts 132a and 132b and the accommodation chambers 133a and 133b shown in Fig. 2.

[0096] The accommodation part 130-3 is configured to accommodate one end portion of the connection electrode 120-2 passing through a through-hole 104-3 and to support the one end portion of the connection electrode 120-2. Similarly, the accommodation part 130-4 is configured to accommodate the other end portion of the connection electrode 120-2 passing through a through-hole 104-4 and to support the other end portion of the connection electrode 120-2. The through-hole 104-3 and the through-hole 104-4 are similar to the above-described through-holes 104a and 104b. The accommodation part 130-3 has a support part 132-3 and an accommodation chamber 133-3, and the accommodation part 130-4 has a support part 132-4 and an accommodation chamber 133-4. The configurations of the support parts 132-3 and 132-4 and the accommodation chambers 133-3 and 133-4 are similar to the configurations of the support parts 132a and 132b and the accommodation chambers 133a and 133b shown in Fig. 2.

[0097] While the embodiments of the present invention have been described, the technical scope of the invention is not limited to the above-described embodiments. It is apparent to persons skilled in the art that various alterations and improvements can be added to the above-described embodiments. It is also apparent from the scope of the claims that the embodiments added with such alterations or improvements can be included in the technical scope of the invention.

EXPLANATION OF REFERENCES

[0098] 1: precipitator, 2: precipitator, 4: first unit, 5: second unit, 10: inner electrode, 12: center, 14: outer circumferential end, 20: outer electrode, 22: outer electrode through-hole, 24: inner wall, 26: outer wall, 30: trapping electrode, 40: internal space, 50: trapping space, 60: combustion part, 100: gas pipe, 101: upstream-side flange part, 102: downstream-side flange part, 103: main body part, 104: through-hole, 110: trapping part, 112: first trapping part group, 120: connection electrode, 121: extension portion, 122: grid part, 123: frame portion, 124: first extension portion, 125: second extension portion,

130: accommodation part, 132: support part, 133: accommodation chamber, 140: sealing part, 142: opening, 150: air pressure maintaining part, 152: voltage applying part, 204: through-hole, 210: trapping part, 212: second trapping part group, 220: connection electrode, 230: accommodation part

Claims

1. A precipitator comprising:

a gas pipe through which a treatment target gas flows from an upstream side toward a downstream side;
a plurality of trapping parts provided for the gas pipe and configured to trap target particles contained in the treatment target gas; and
a connection electrode connected to the plurality of trapping parts, wherein
each of the plurality of trapping parts has:

a tubular outer electrode having an internal space through which the treatment target gas passes, and
an inner electrode arranged coaxially with the outer electrode in the internal space,
the plurality of trapping parts is arranged in parallel in a cross section of the gas pipe, and
the connection electrode is connected to the respective inner electrodes of the plurality of trapping parts and is also arranged on a further downstream side than the plurality of trapping parts.

2. The precipitator according to Claim 1, wherein

the connection electrode has a grid part where an electrode is provided in a grid pattern, and the grid part is connected to the respective inner electrodes.

3. The precipitator according to Claim 2, wherein

a diameter of the electrode provided for the connection electrode in the grid pattern is greater than a diameter of the inner electrode.

4. The precipitator according to any one of Claims 1 to 3, further comprising a sealing part configured to seal a space between the trapping parts in the plurality of trapping parts.

5. The precipitator according to Claim 4, wherein

the sealing part is provided at end portions on the upstream side of the plurality of trapping parts.

6. The precipitator according to any one of Claims 1 to

- 5, wherein
a distance between the connection electrode and a wall of the gas pipe is greater than an inner diameter of the outer electrode.
7. The precipitator according to any one of Claims 1 to 6, wherein
the at least one outer electrode has a length in an axis direction different from the other outer electrodes.
8. The precipitator according to Claim 7, wherein
among the plurality of outer electrodes, the outer electrode arranged in a centermost position on a cross section of the gas pipe is longer than the other outer electrodes.
9. The precipitator according to Claim 7 or 8, wherein
the respective outer electrodes are the same in terms of positions of end portions on an upstream side.
10. The precipitator according to any one of Claims 1 to 9, wherein
a wall of the gas pipe is provided with a through-hole through which the connection electrode passes,
further comprising an accommodation part arranged outside the gas pipe and configured to accommodate an end portion of the connection electrode passing through the through-hole and to support the end portion of the connection electrode, and
the through-hole is arranged on a further downstream side than the plurality of trapping parts.
11. The precipitator according to Claim 10, further comprising an air pressure maintaining part configured to maintain an air pressure in the accommodation part to be higher than an air pressure in the gas pipe.
12. The precipitator according to Claim 10 or 11, wherein
a radius of the through-hole is greater than an inner diameter of the outer electrode.
13. The precipitator according to any one of Claims 1 to 12, comprising:
a first trapping part group having the plurality of trapping parts provided for the gas pipe and arranged in parallel in a cross section of the gas pipe;
a second trapping part group provided on a further upstream side than the first trapping part group in the gas pipe and having the plurality of trapping parts arranged in parallel in a cross section of the gas pipe;
the first connection electrode arranged on a fur-

ther downstream side than the first trapping part group and connected to the respective inner electrodes of the first trapping part group; and
the second connection electrode arranged between the second trapping part group and the first trapping part group and connected to the respective inner electrodes of the second trapping part group.

Amended claims under Art. 19.1 PCT

1. A precipitator comprising:
a gas pipe through which a treatment target gas flows from an upstream side toward a downstream side;
a plurality of trapping parts provided for the gas pipe and configured to trap target particles contained in the treatment target gas; and
a connection electrode connected to the plurality of trapping parts, wherein
each of the plurality of trapping parts has:
a tubular outer electrode having an internal space through which the treatment target gas passes, and
an inner electrode arranged coaxially with the outer electrode in the internal space,
the plurality of trapping parts is arranged in parallel in a cross section of the gas pipe, and
the connection electrode is connected to the respective inner electrodes of the plurality of trapping parts and is also arranged on a further downstream side than the plurality of trapping parts.
2. The precipitator according to Claim 1, wherein
the connection electrode has a grid part where an electrode is provided in a grid pattern, and the grid part is connected to the respective inner electrodes.
3. The precipitator according to Claim 2, wherein
a diameter of the electrode provided for the connection electrode in the grid pattern is greater than a diameter of the inner electrode.
4. The precipitator according to any one of Claims 1 to 3, further comprising a sealing part configured to seal a space between the trapping parts in the plurality of trapping parts.
5. The precipitator according to Claim 4, wherein
the sealing part is provided at end portions on the upstream side of the plurality of trapping parts.

- 6. The precipitator according to any one of Claims 1 to 5, wherein a distance between the connection electrode and a wall of the gas pipe is greater than an inner diameter of the outer electrode. 5
- 7. The precipitator according to any one of Claims 1 to 6, wherein the at least one outer electrode has a length in an axis direction different from the other outer electrodes. 10
- 8. The precipitator according to Claim 7, wherein among the plurality of outer electrodes, the outer electrode arranged in a centermost position on a cross section of the gas pipe is longer than the other outer electrodes. 15
- 9. The precipitator according to Claim 7 or 8, wherein the respective outer electrodes are the same in terms of positions of end portions on an upstream side. 20
- 10. The precipitator according to any one of Claims 1 to 9, wherein 25
 - a wall of the gas pipe is provided with a through-hole through which the connection electrode passes, 30
 - further comprising an accommodation part arranged outside the gas pipe and configured to accommodate an end portion of the connection electrode passing through the through-hole and to support the end portion of the connection electrode, and 35
 - the through-hole is arranged on a further downstream side than the plurality of trapping parts.
- 11. The precipitator according to Claim 10, further comprising an air pressure maintaining part configured to maintain an air pressure in the accommodation part to be higher than an air pressure in the gas pipe. 40
- 12. The precipitator according to Claim 10 or 11, wherein a radius of the through-hole is greater than an inner diameter of the outer electrode. 45
- 13. The precipitator according to any one of Claims 1 to 12, comprising: 50
 - a first trapping part group having the plurality of trapping parts provided for the gas pipe and arranged in parallel in a cross section of the gas pipe; 55
 - a second trapping part group provided on a further upstream side than the first trapping part group in the gas pipe and having the plurality of trapping parts arranged in parallel in a cross section of the gas pipe;

the first connection electrode arranged on a further downstream side than the first trapping part group and connected to the respective inner electrodes of the first trapping part group; and the second connection electrode arranged between the second trapping part group and the first trapping part group and connected to the respective inner electrodes of the second trapping part group.

- 14. The precipitator according to any one of Claims 1 to 13, wherein each of the plurality of trapping parts further has a tubular trapping electrode arranged to surround an outside of each of the outer electrodes.
- 15. The precipitator according to Claim 14, further comprising a sealing part configured to seal a space between the trapping parts in the plurality of trapping parts, wherein the plurality of outer electrodes and the plurality of trapping electrodes are fixed to the sealing part.
- 16. The precipitator according to any one of Claims 1 to 13, further comprising a trapping electrode arranged to collectively surround the plurality of outer electrodes arranged in parallel.

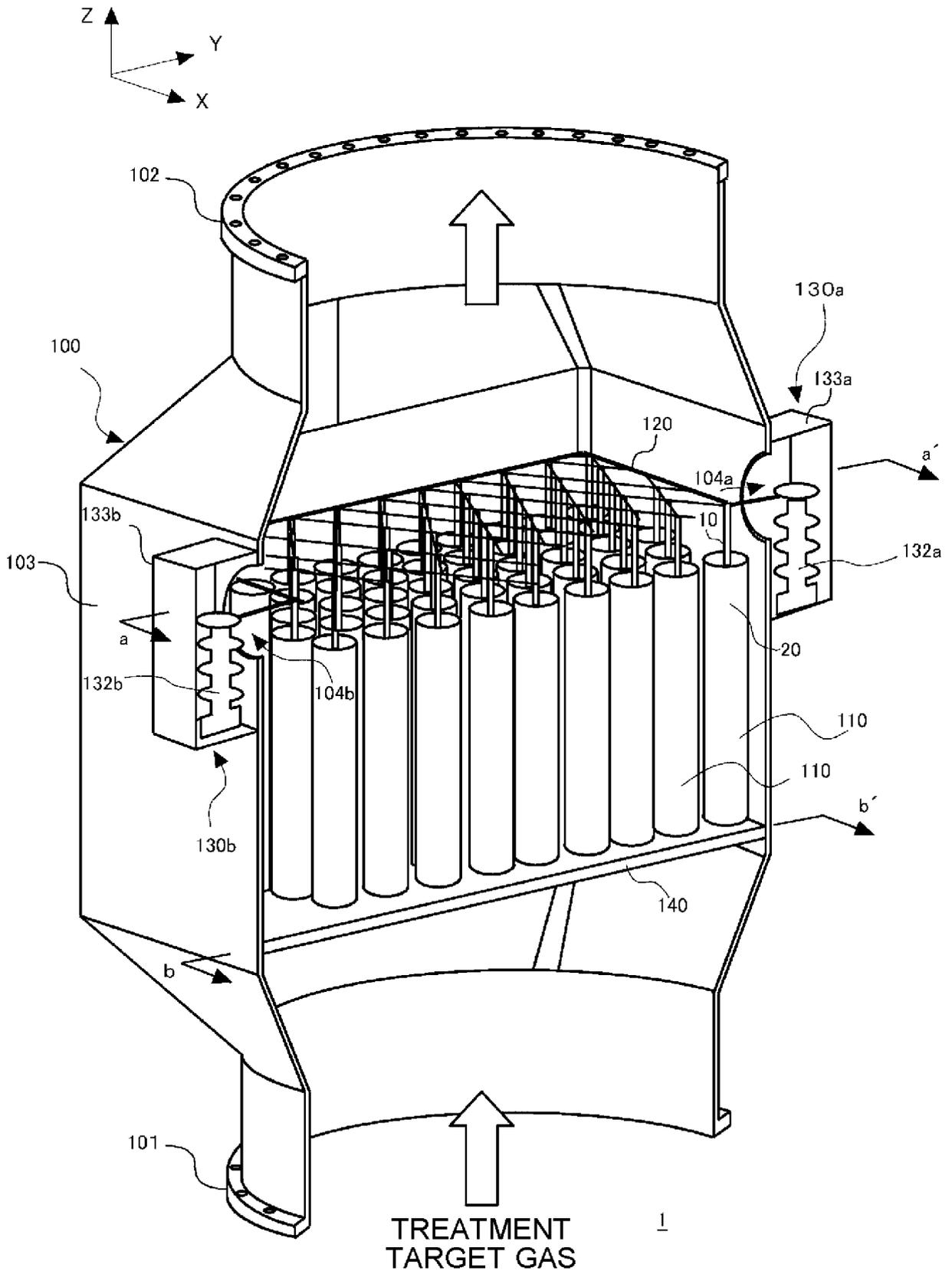


FIG.1

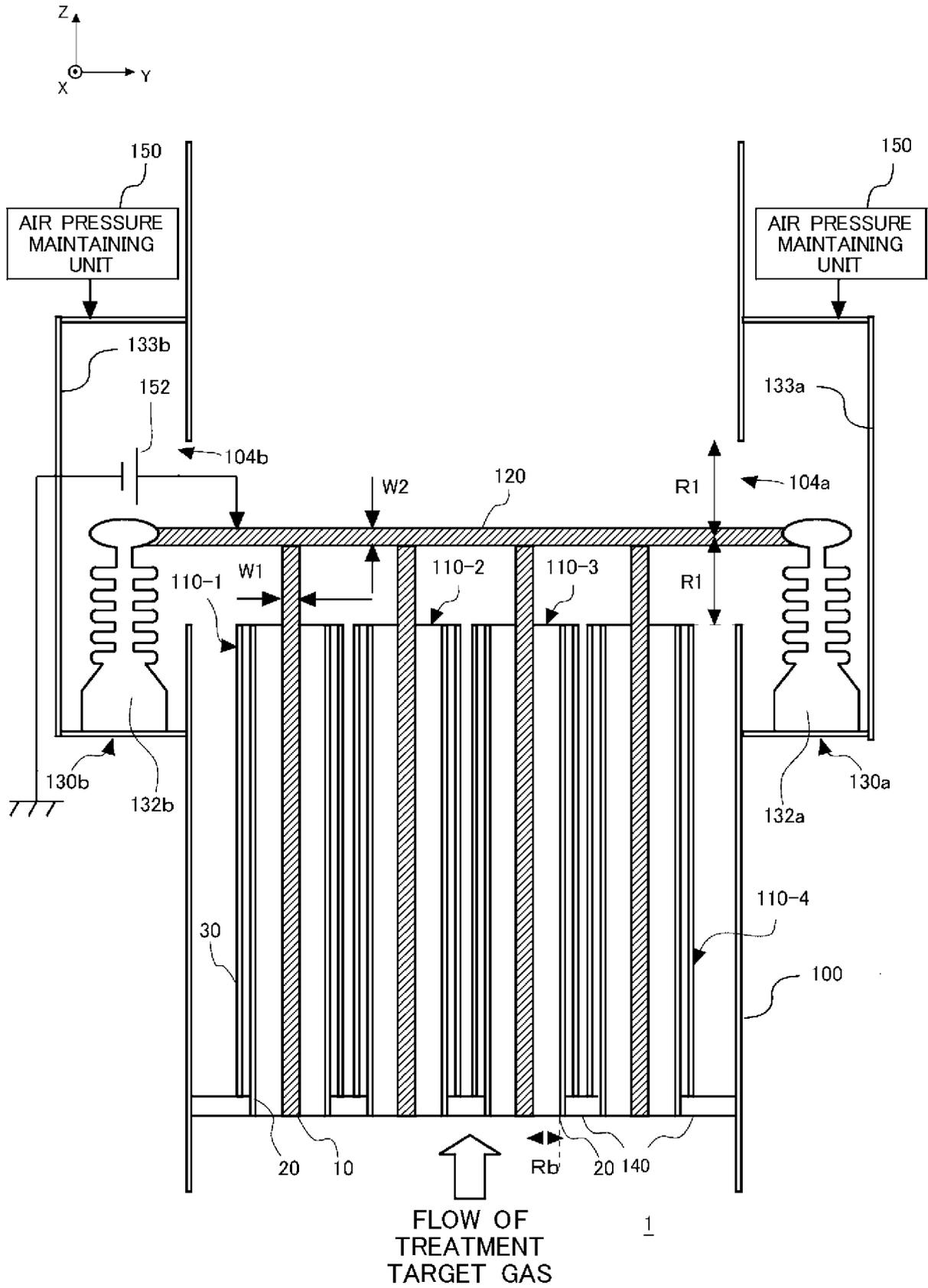


FIG.2

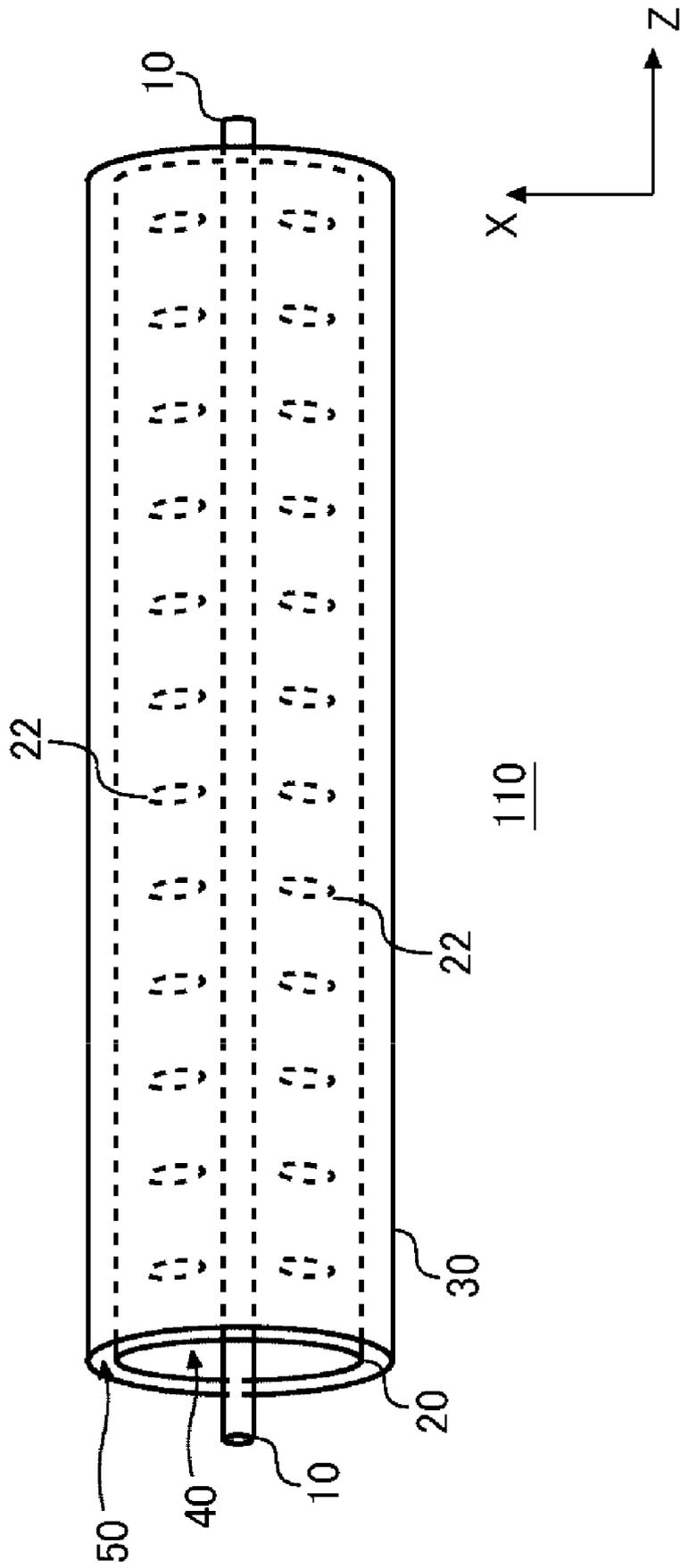
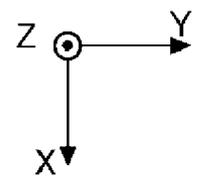
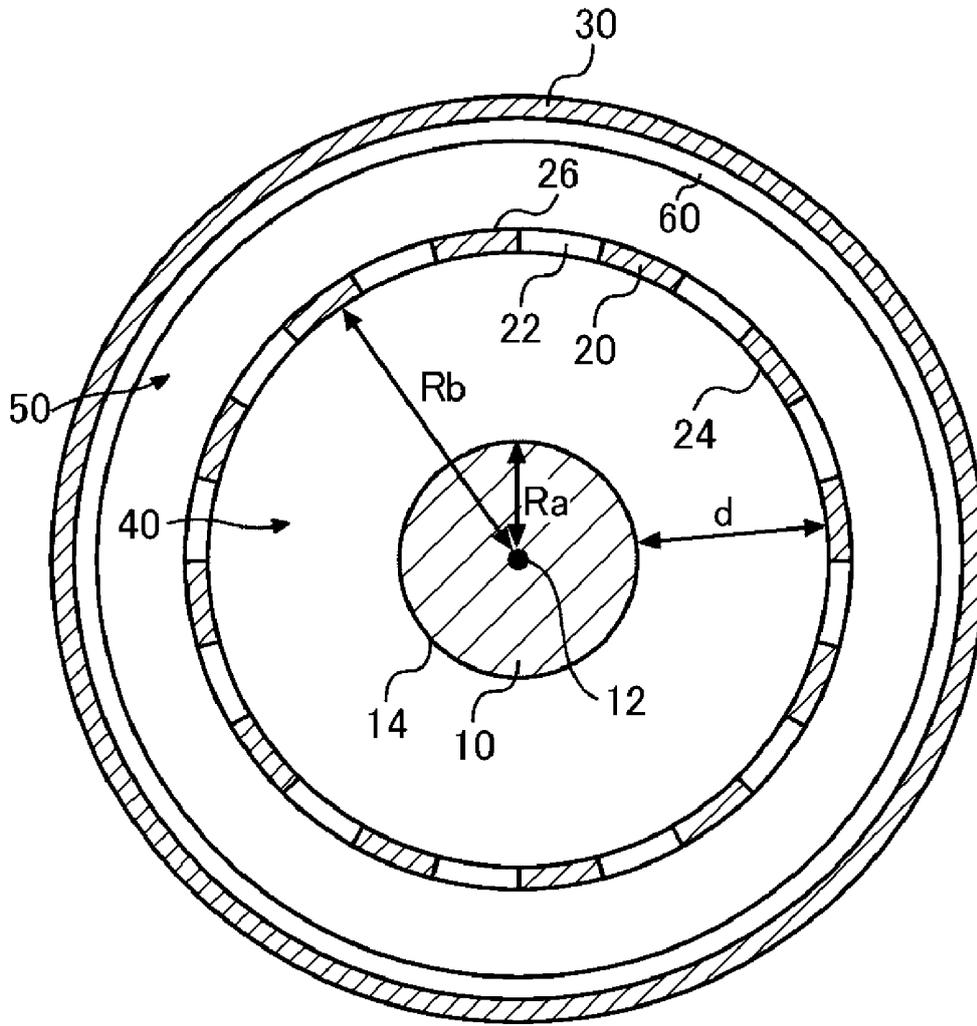
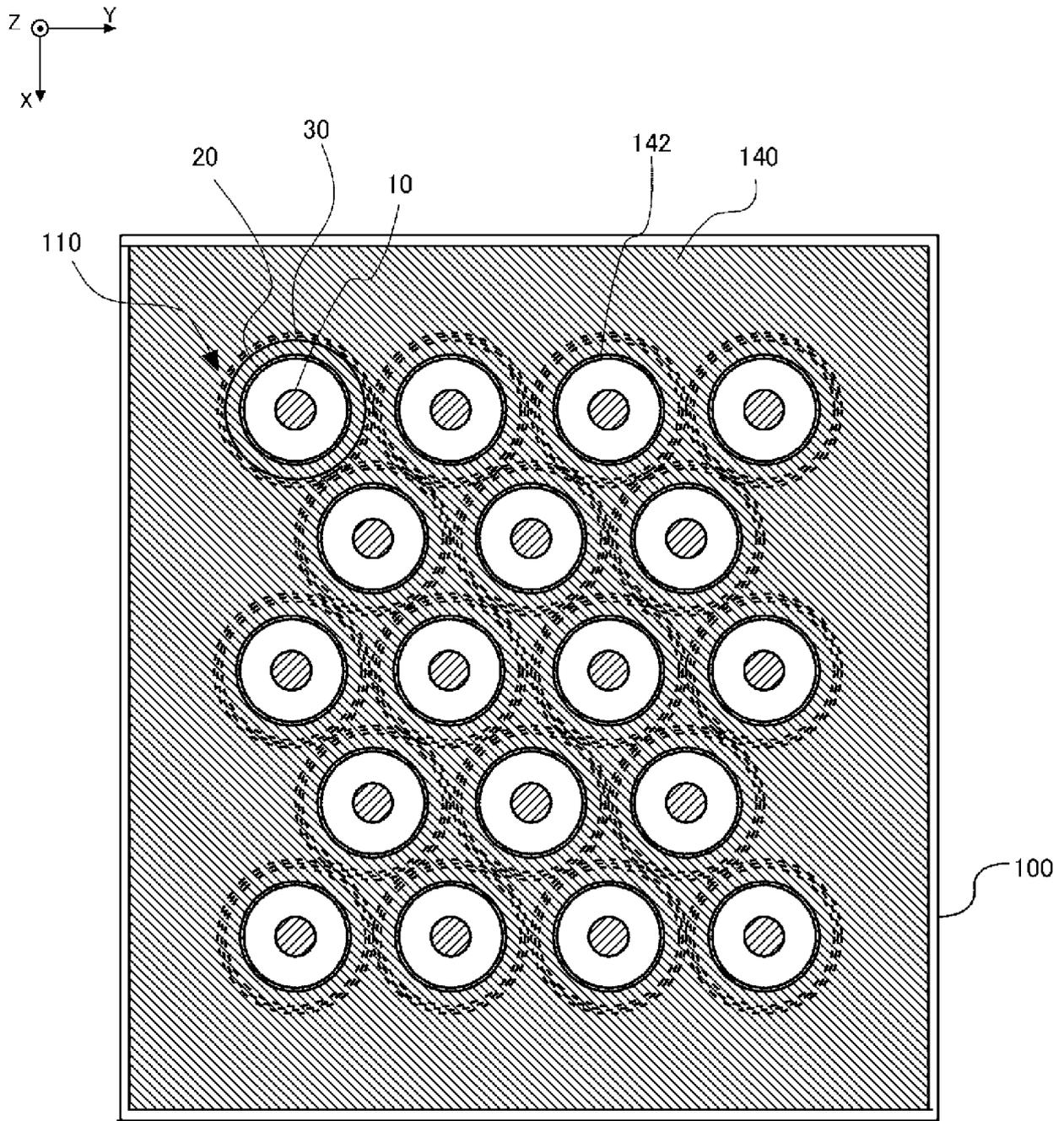


FIG. 3



110

FIG.4



b-b'

1

FIG.6

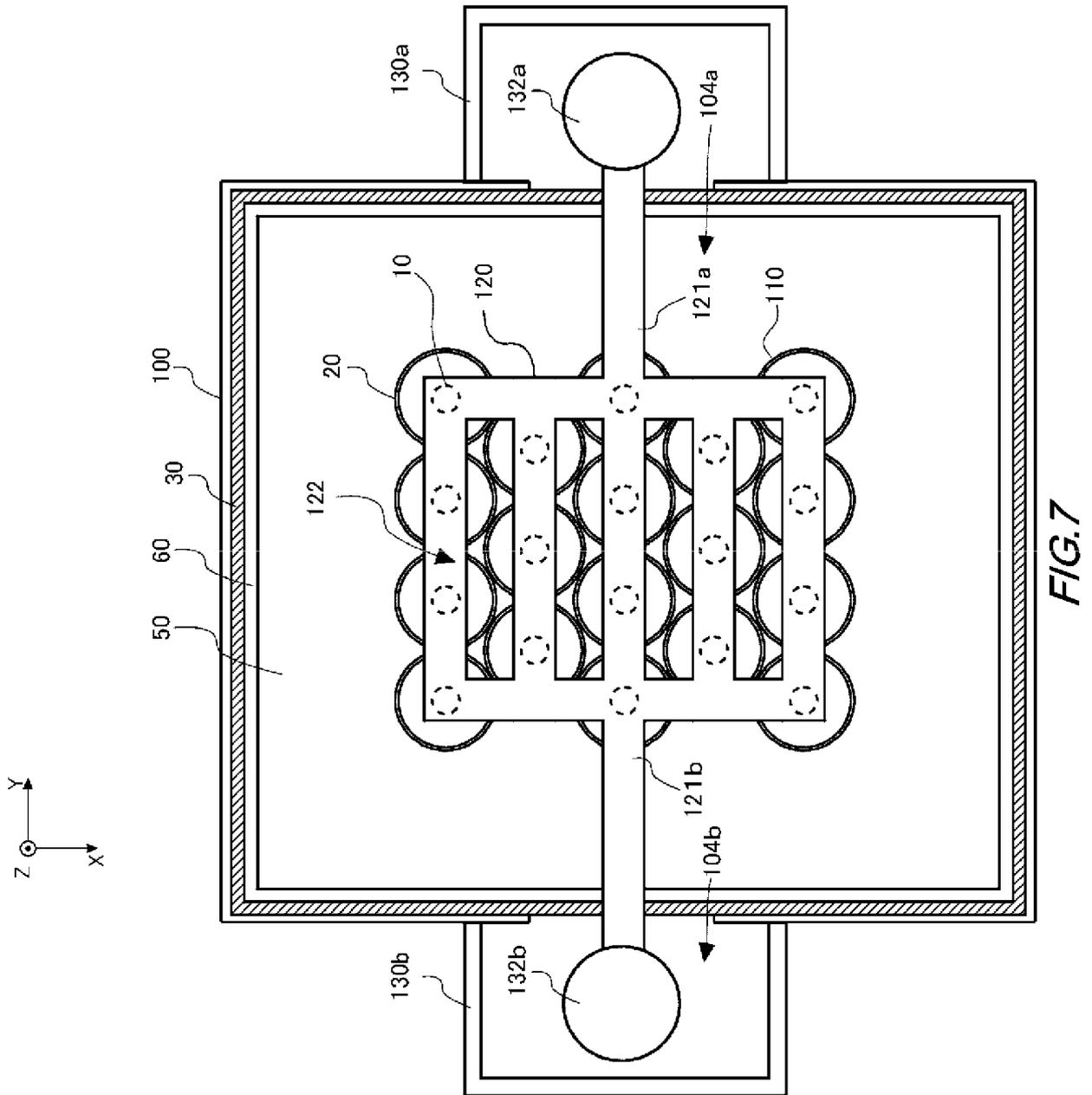


FIG. 7

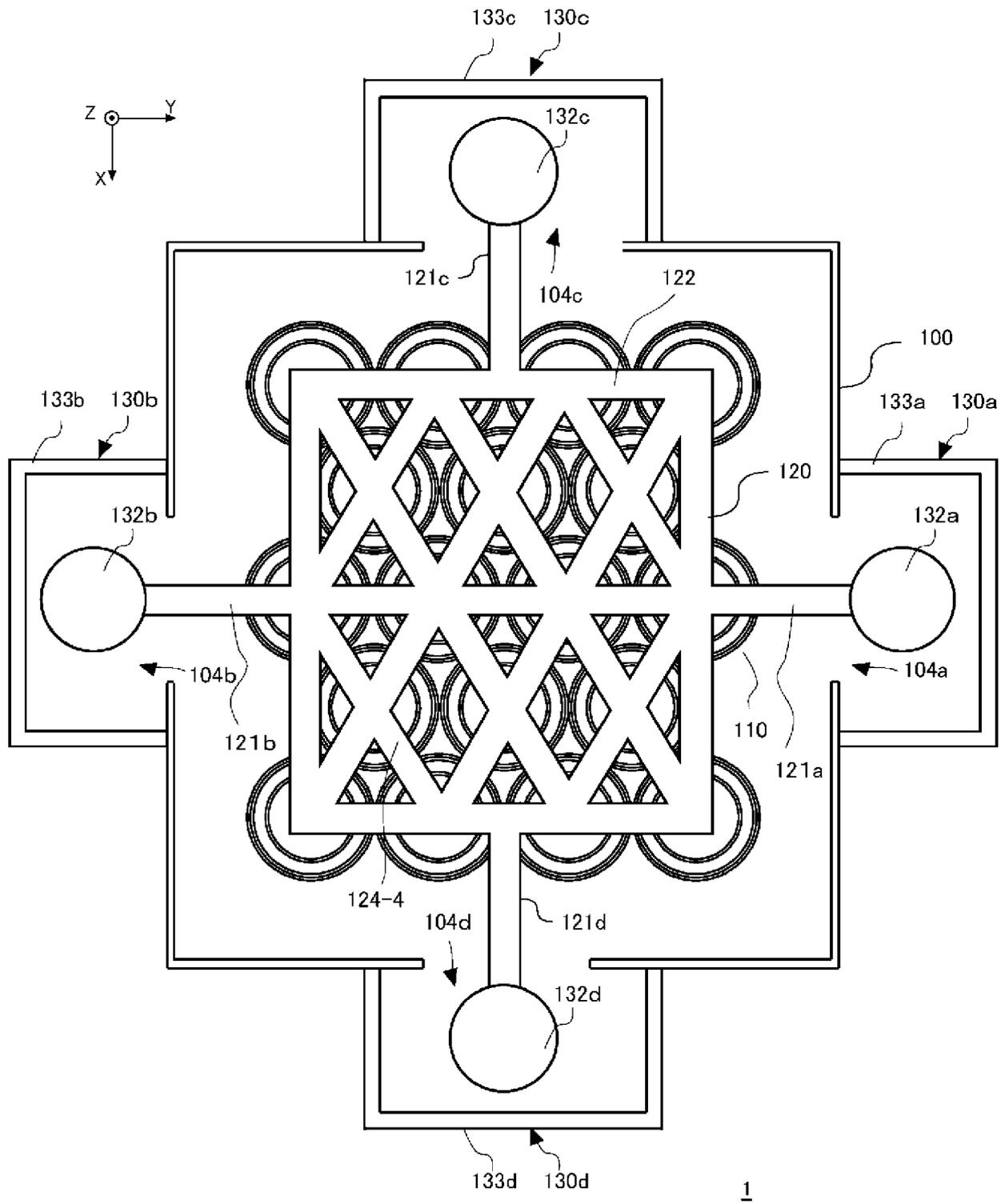


FIG. 8

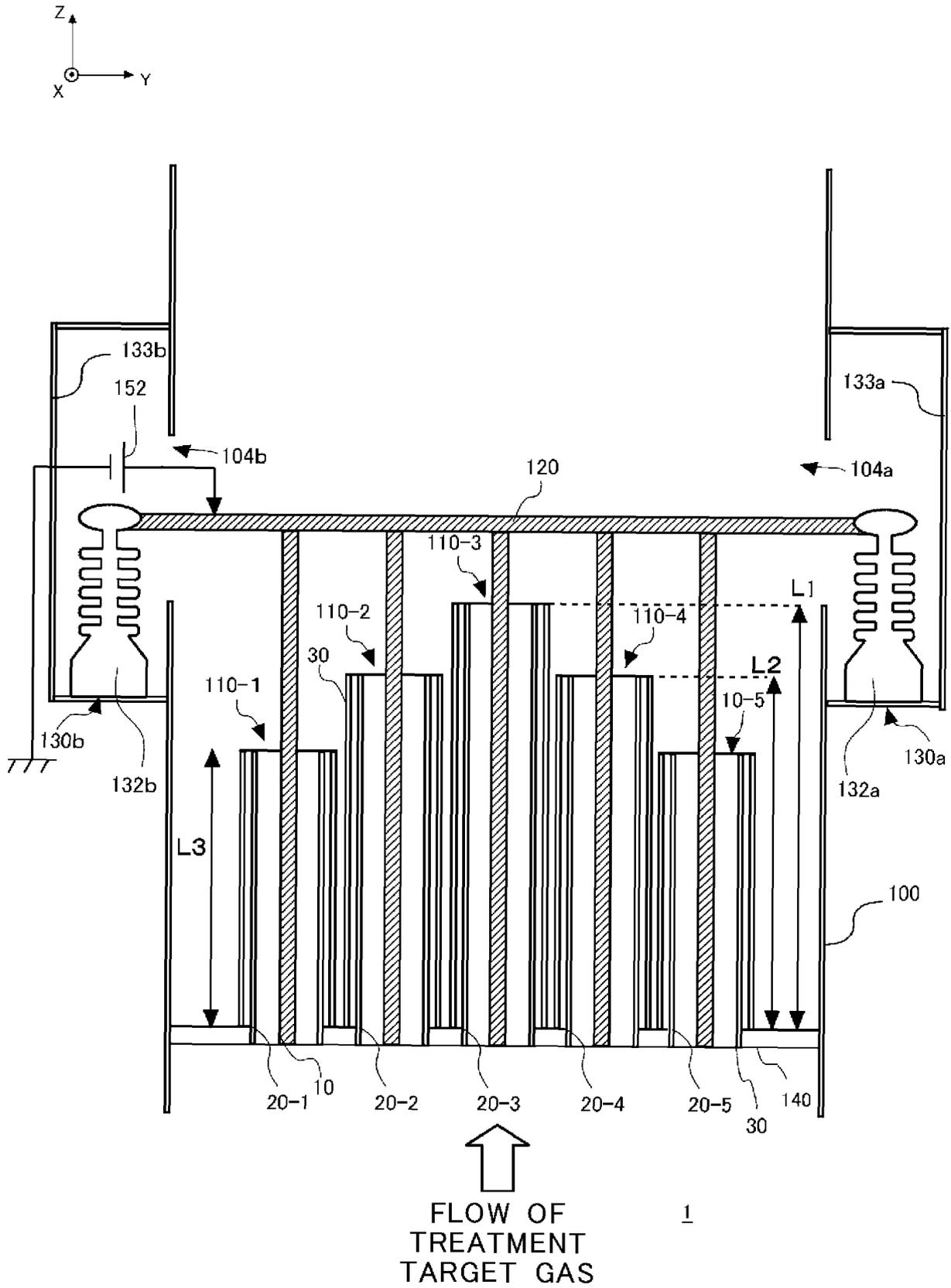


FIG. 9

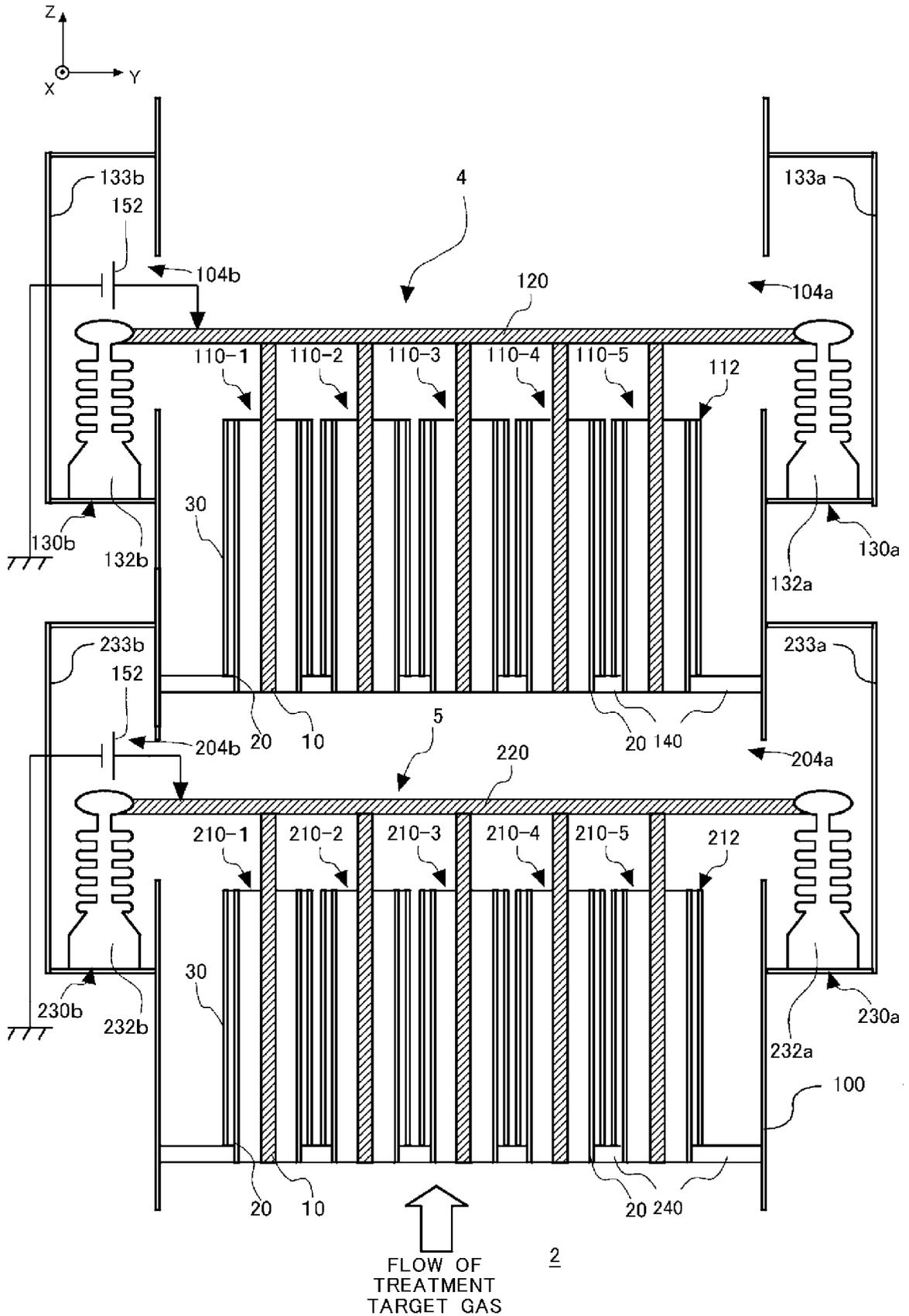
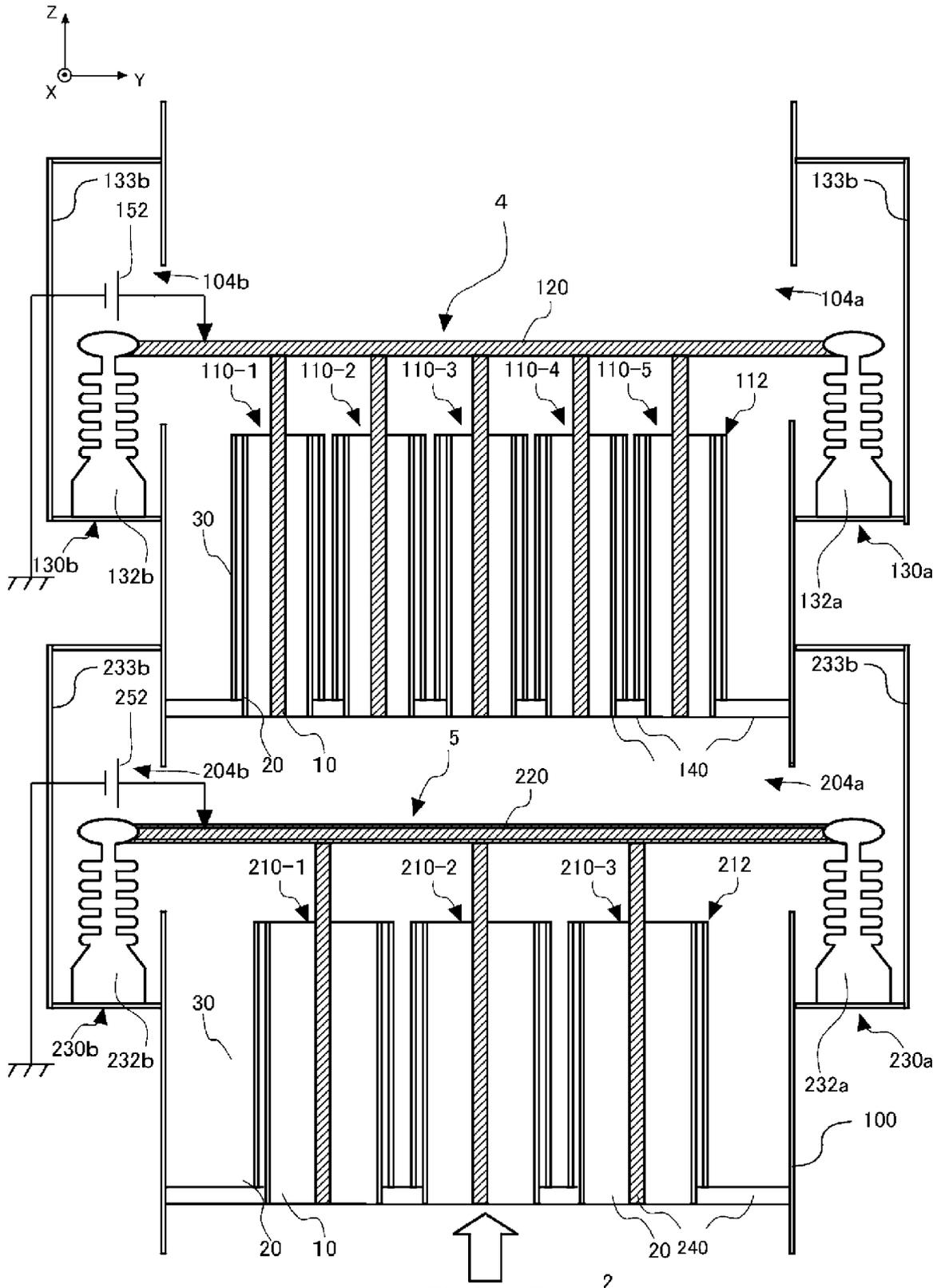
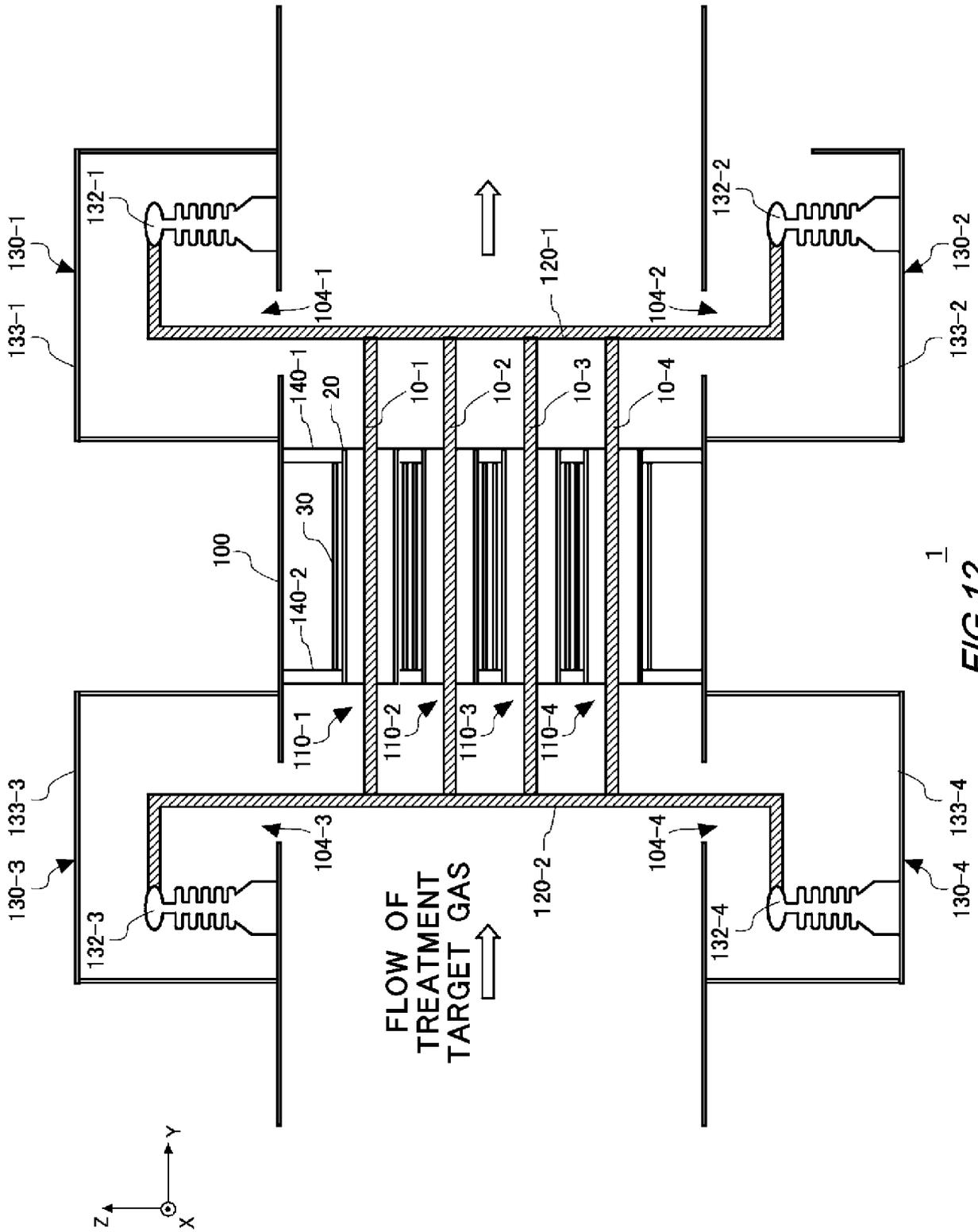


FIG. 10



FLOW OF
TREATMENT
TARGET GAS
FIG.11



5	INTERNATIONAL SEARCH REPORT	International application No. PCT/JP2021/002341
	A. CLASSIFICATION OF SUBJECT MATTER	
	Int.Cl. B03C3/41(2006.01)i, B03C3/40(2006.01)i, B03C3/49(2006.01)i, F01N3/01(2006.01)i FI: B03C3/41H, B03C3/40A, B03C3/49, F01N3/01 According to International Patent Classification (IPC) or to both national classification and IPC	
10	B. FIELDS SEARCHED	
	Minimum documentation searched (classification system followed by classification symbols) Int.Cl. B03C3/00-11/00, F01N3/01	
15	Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched	
	Published examined utility model applications of Japan	1922-1996
	Published unexamined utility model applications of Japan	1971-2021
	Registered utility model specifications of Japan	1996-2021
20	Published registered utility model applications of Japan	1994-2021
	Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)	
	C. DOCUMENTS CONSIDERED TO BE RELEVANT	
25	Category*	Citation of document, with indication, where appropriate, of the relevant passages
	X	JP 57-056056 A (FUJI ELECTRIC CO., LTD.) 03 April 1982
	Y	(1982-04-03), claims, page 2, upper right column, line
	A	19 to lower right column, line 13, fig. 3-6
		1-7, 9-12
		4-5, 13
		8
30	Y	JP 2012-192362 A (FUJI ELECTRIC CO., LTD.) 11 October
		2012 (2012-10-11), claims, fig. 6
		4-5
	Y	JP 2011-245429 A (FUJI ELECTRIC CO., LTD.) 08 December
		2011 (2011-12-08), claims, fig. 3
		4-5
35	Y	JP 10-235224 A (OMI KOGYO KK) 08 September 1998
		(1998-09-08), claims, fig. 1
		13
	A	CN 106513175 A (PENGZHOU YUNDA INTELLECTUAL PROPERTY
		SERVICES CO., LTD.) 22 March 2017 (2017-03-22)
		1-13
40	<input type="checkbox"/> Further documents are listed in the continuation of Box C.	<input checked="" type="checkbox"/> 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	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
45	"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
	"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
	"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
	"P" document published prior to the international filing date but later than the priority date claimed	
50	Date of the actual completion of the international search 31 March 2021	Date of mailing of the international search report 13 April 2021
55	Name and mailing address of the ISA/ Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Authorized officer Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/002341

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JP 57-056056 A	03 April 1982	(Family: none)
JP 2012-192362 A	11 October 2012	(Family: none)
JP 2011-245429 A	08 December 2011	(Family: none)
JP 10-235224 A	08 September 1998	(Family: none)
CN 106513175 A	22 March 2017	(Family: none)

REFERENCES CITED IN THE DESCRIPTION

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- JP 2012170869 A [0002]
- JP 2011245429 A [0002]
- JP 2009166006 A [0002]

Non-patent literature cited in the description

- High voltage engineering. Asakura Publishing Co. Ltd. KOUNO Teruya, 28-29 [0057]