US 20080268387A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2008/0268387 A1
(43) Pub. Date: Oct. 30, 2008
Saito et al.

(54) COMBUSTION EQUIPMENT AND BURNER COMBUSTION METHOD

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(21) Appl. No.: 12/108,595

(22) Filed: Apr. 24, 2008

(30) Foreign Application Priority Data

Apr. 26, 2007 (JP) 2007-116304
Mar. 31, 2008 (JP) 2008-089152

Publication Classification

(51) Int. Cl.
F23C 5/00 (2006.01)

(52) U.S. Cl. 431/8; 431/174

(57) ABSTRACT

Combustion equipment of a coaxial jet combustion scheme is provided that includes: a burner plate in which fuel and air are mixed with each other while the fuel and air pass through an air hole; a burner plate extension which is a portion of the burner plate and extends toward a combustion chamber side spaced apart from the air hole; and a protrusion disposed on the combustion chamber side of the burner plate extension so as to protrude in a direction where flow of the fuel moves. In the combustion equipment, a gap between opposite portions of the protrusion is greater than a diameter of the air hole and a flame source forming area is defined between the burner plate, the burner plate extension and the protrusion. The combustion equipment of a coaxial jet combustion scheme can achieve a further reduction in NOx emissions.

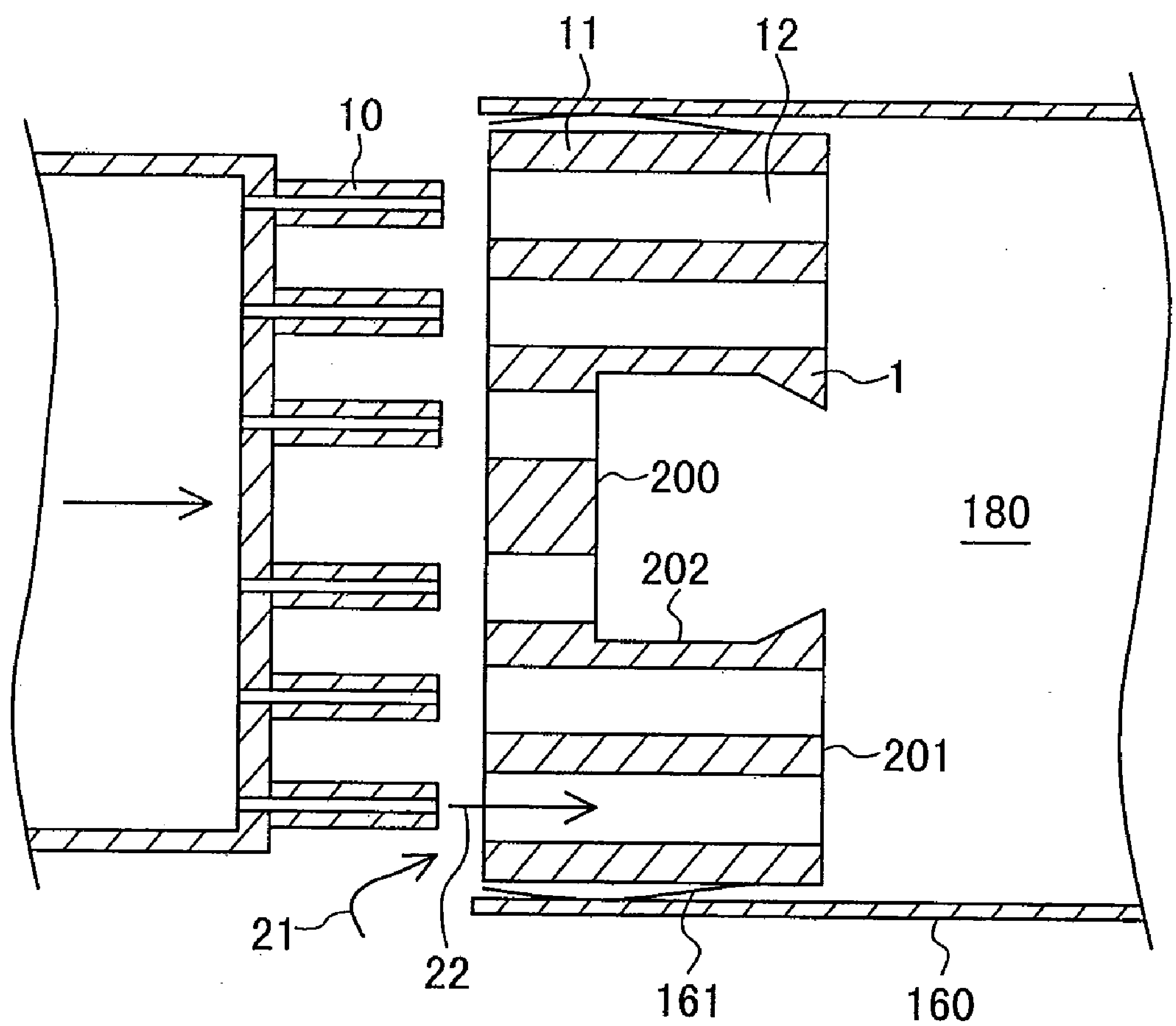


FIG.1A

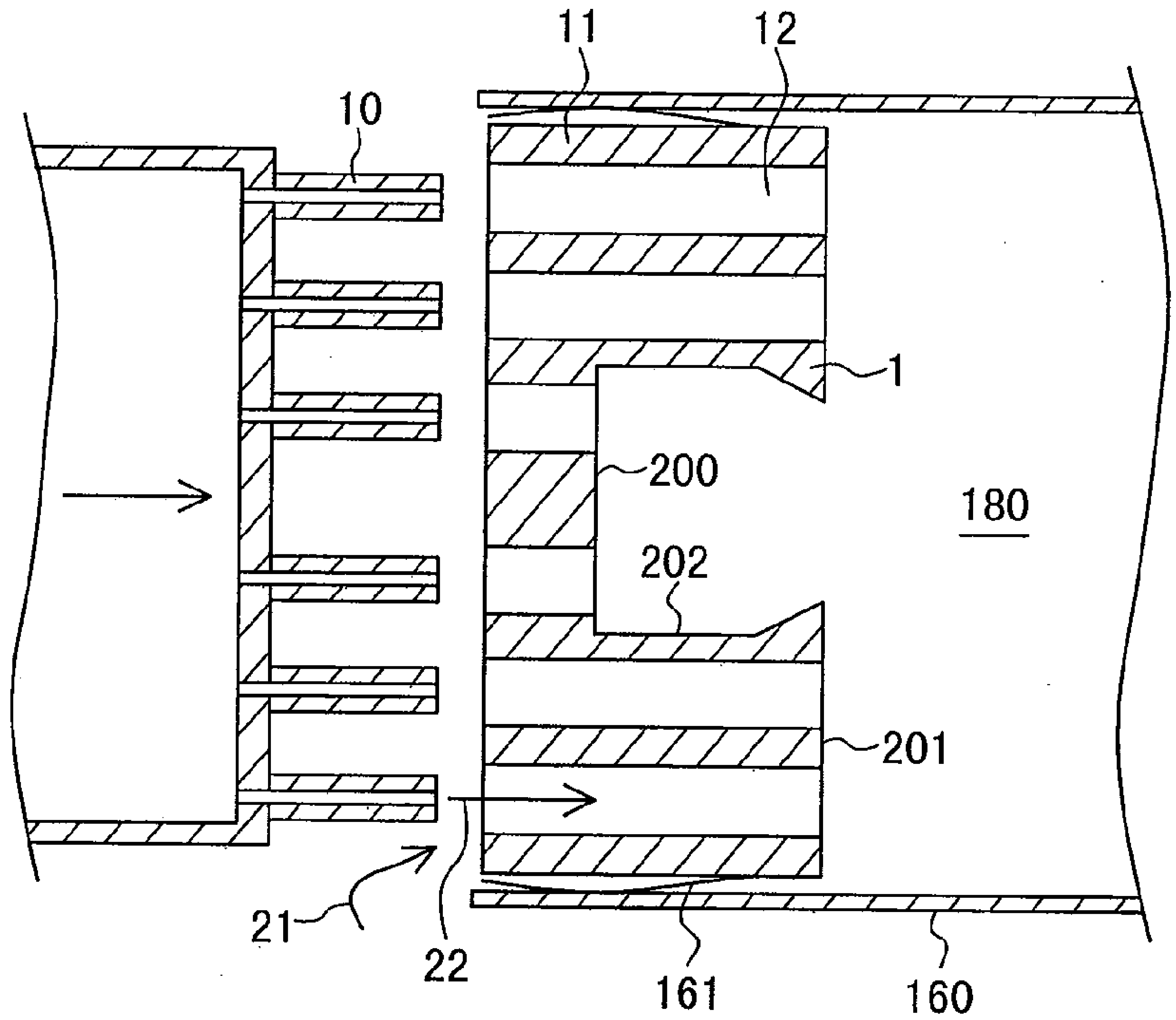


FIG.1B

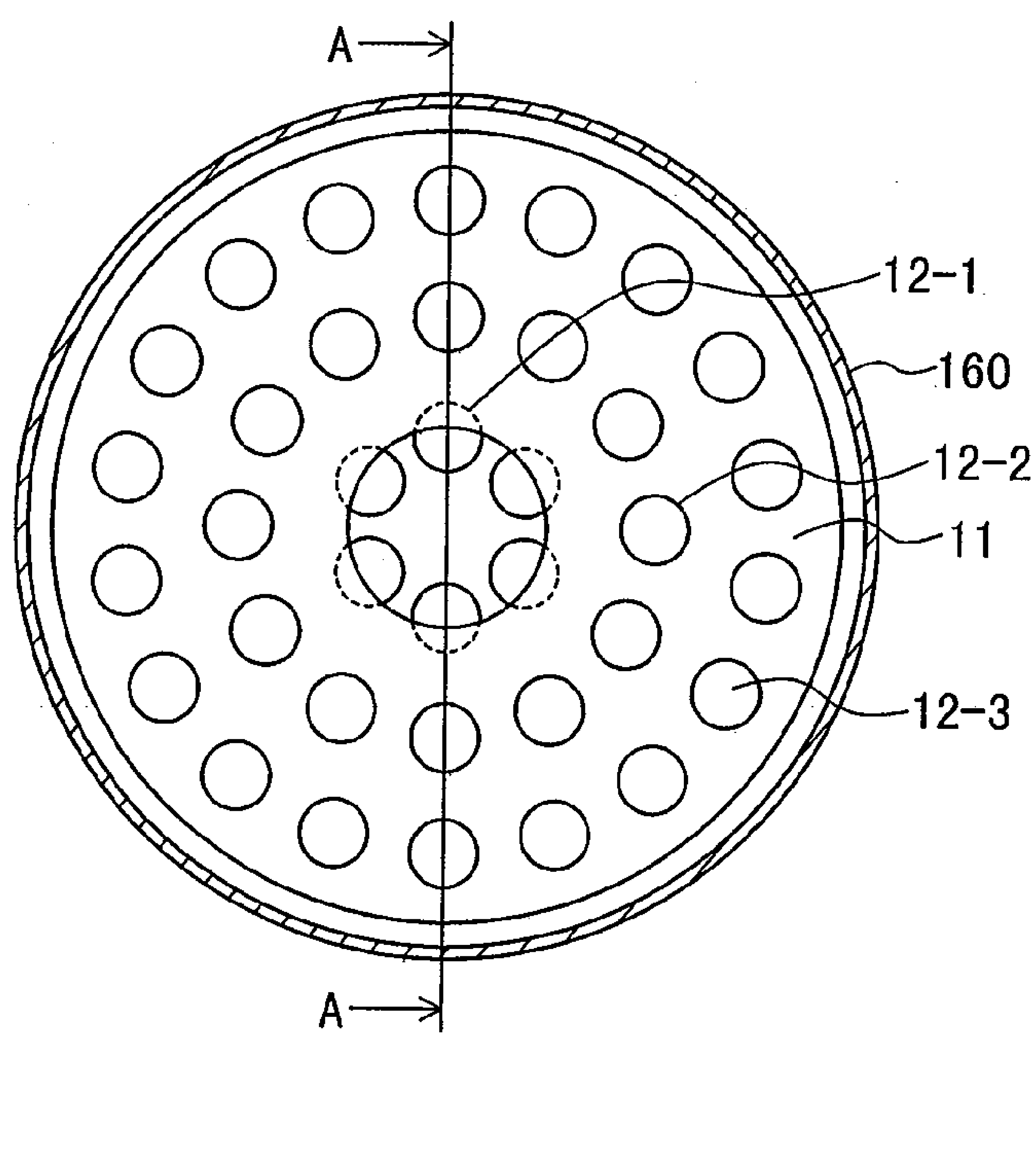


FIG.2A

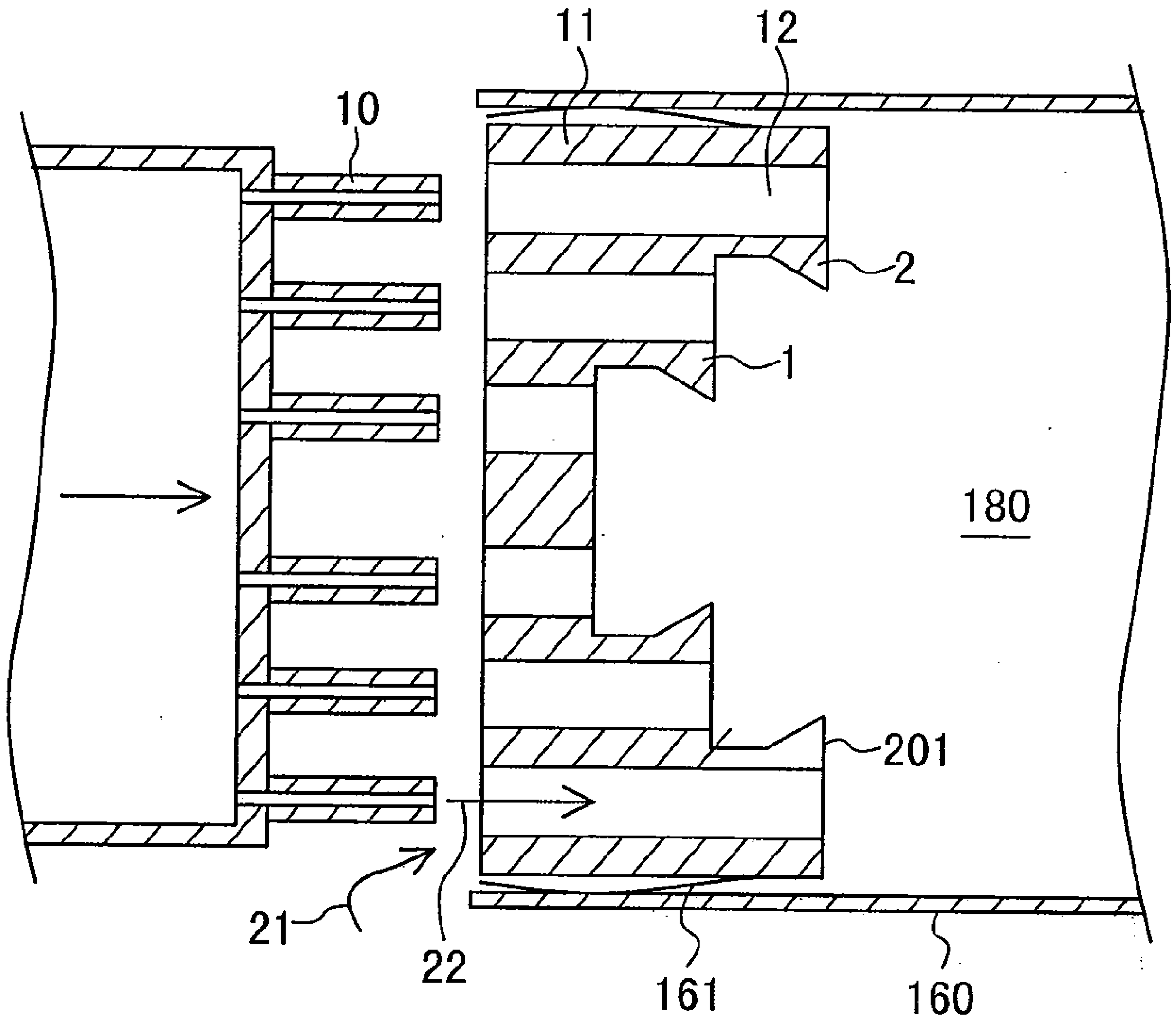


FIG.2B

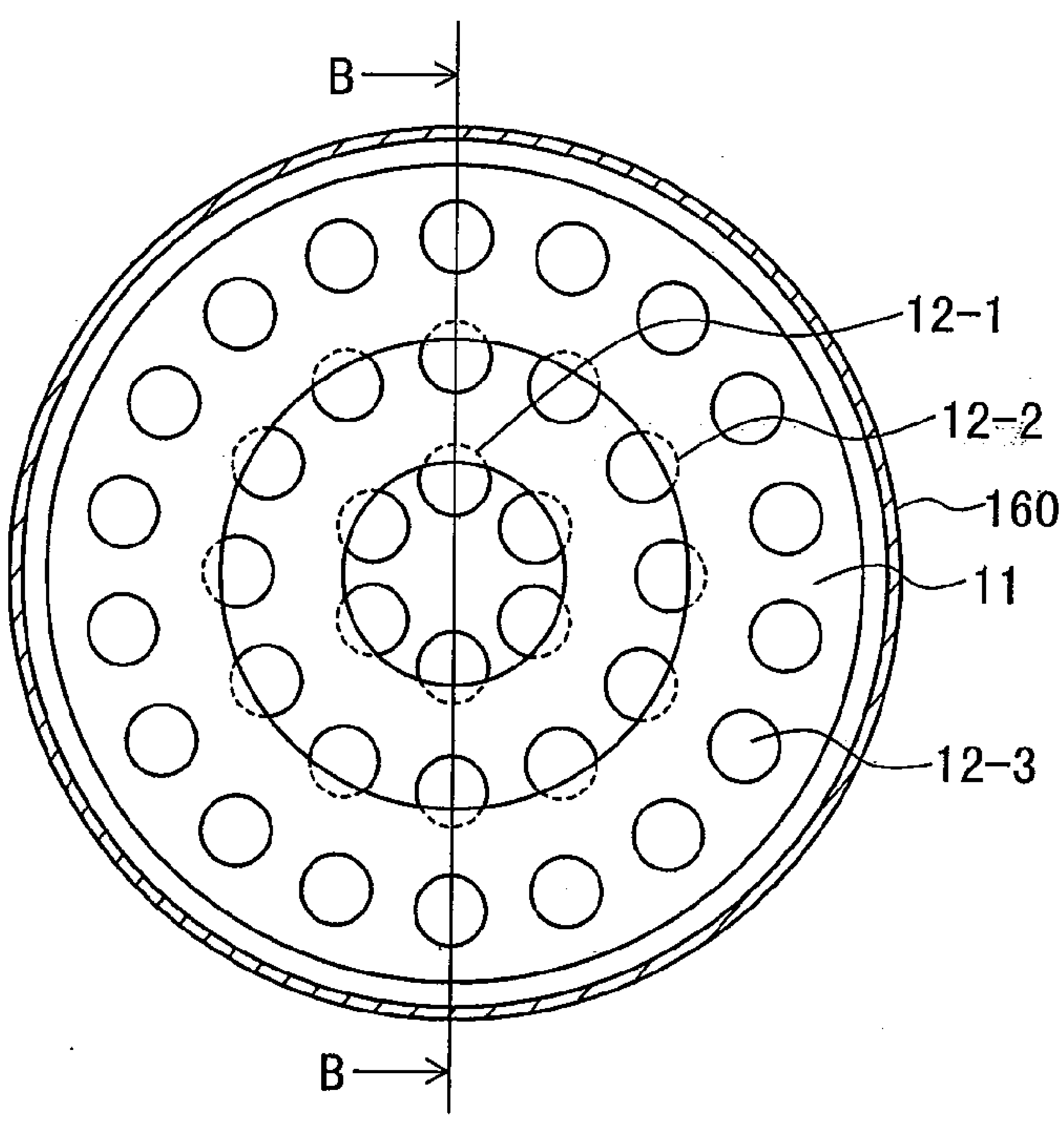


FIG.3A

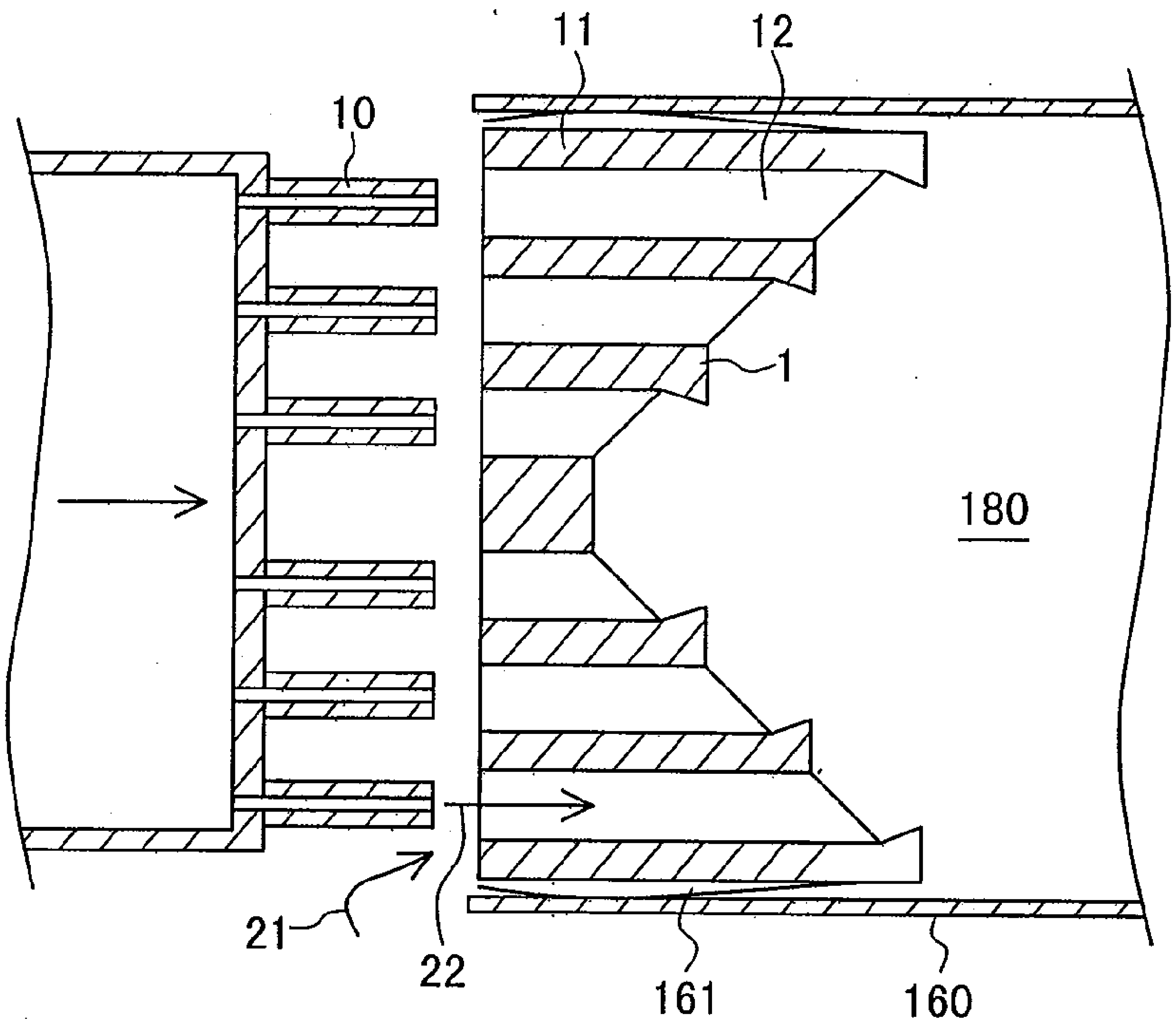


FIG.3B

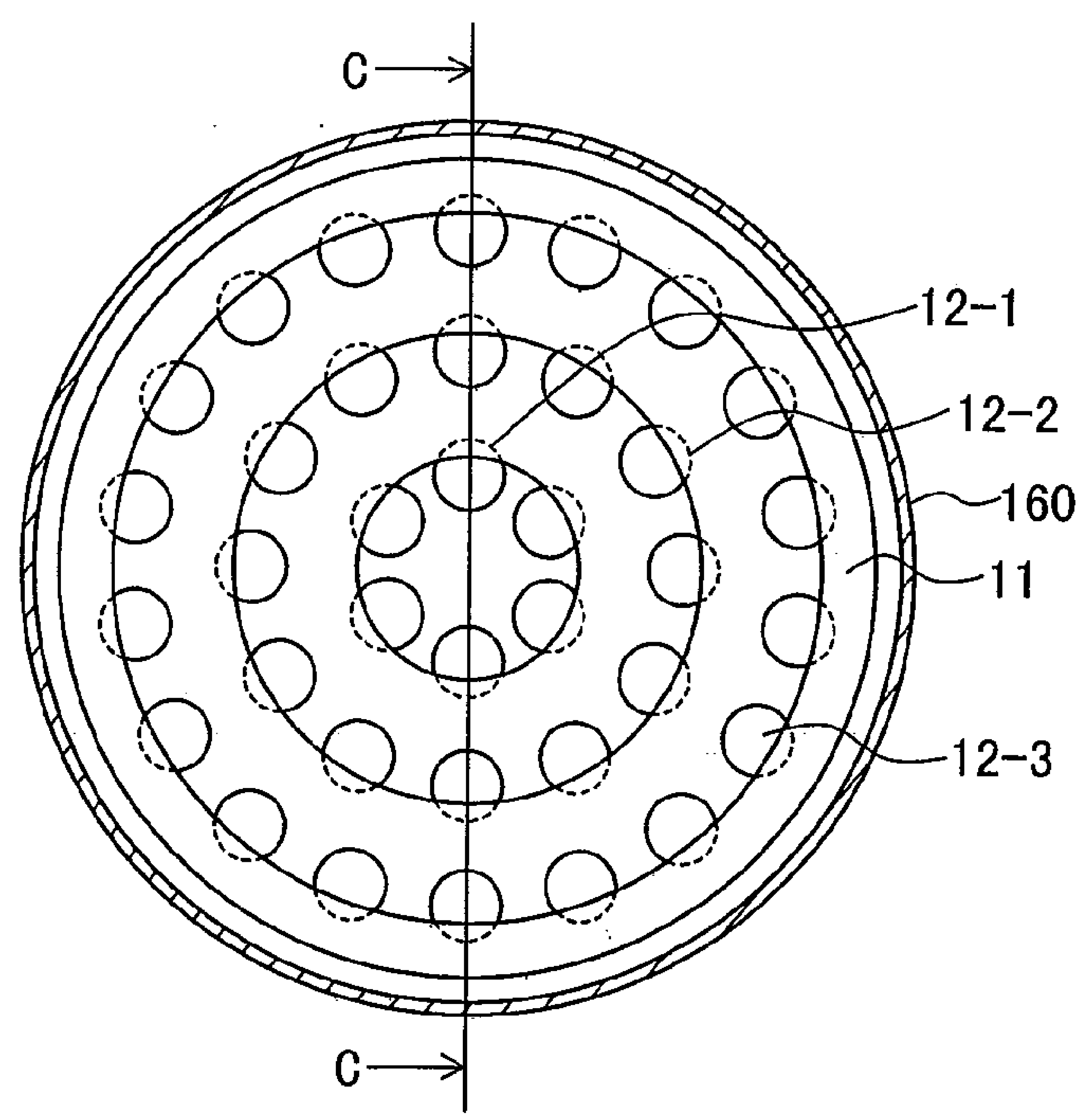


FIG.4A

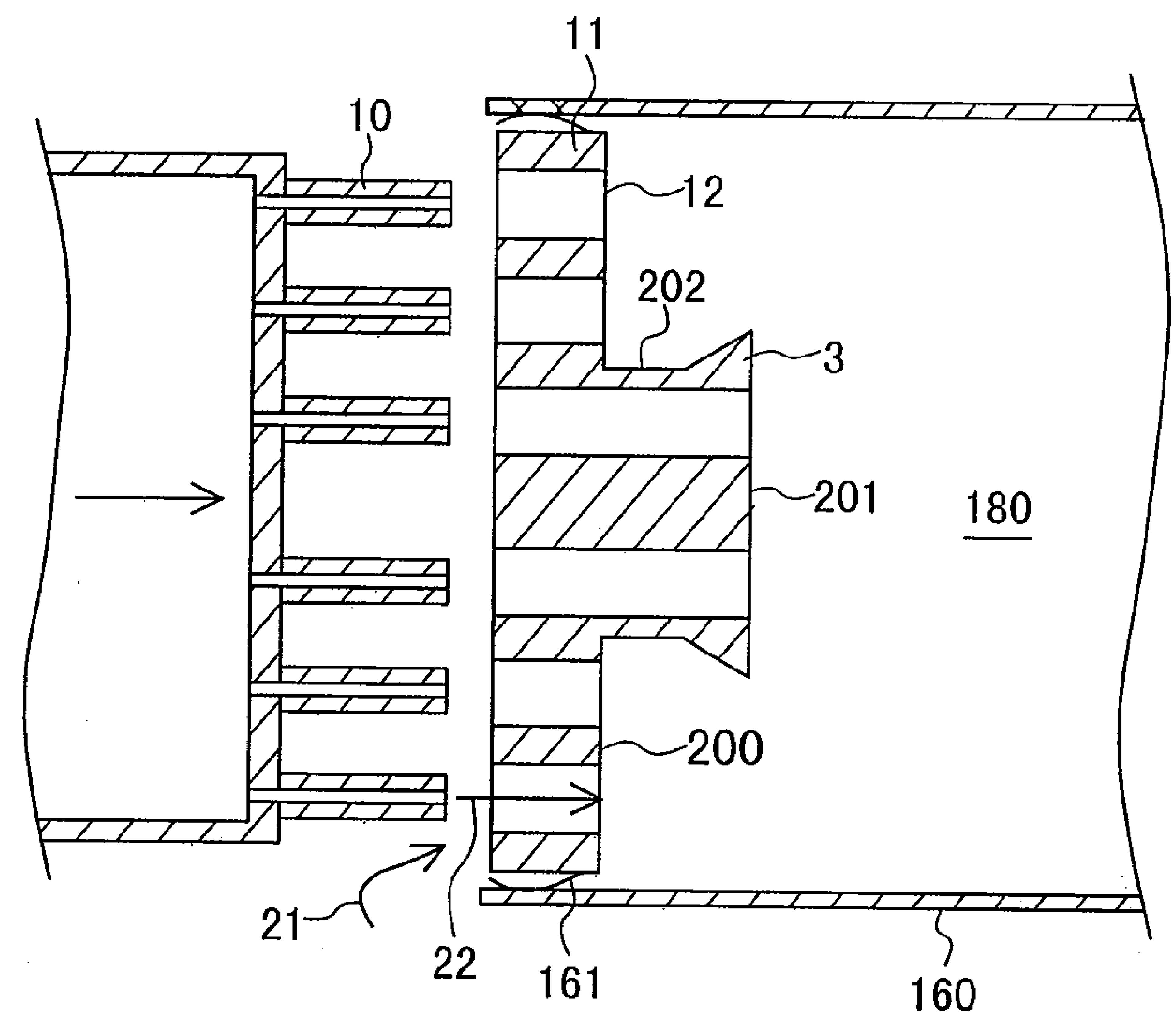


FIG.4B

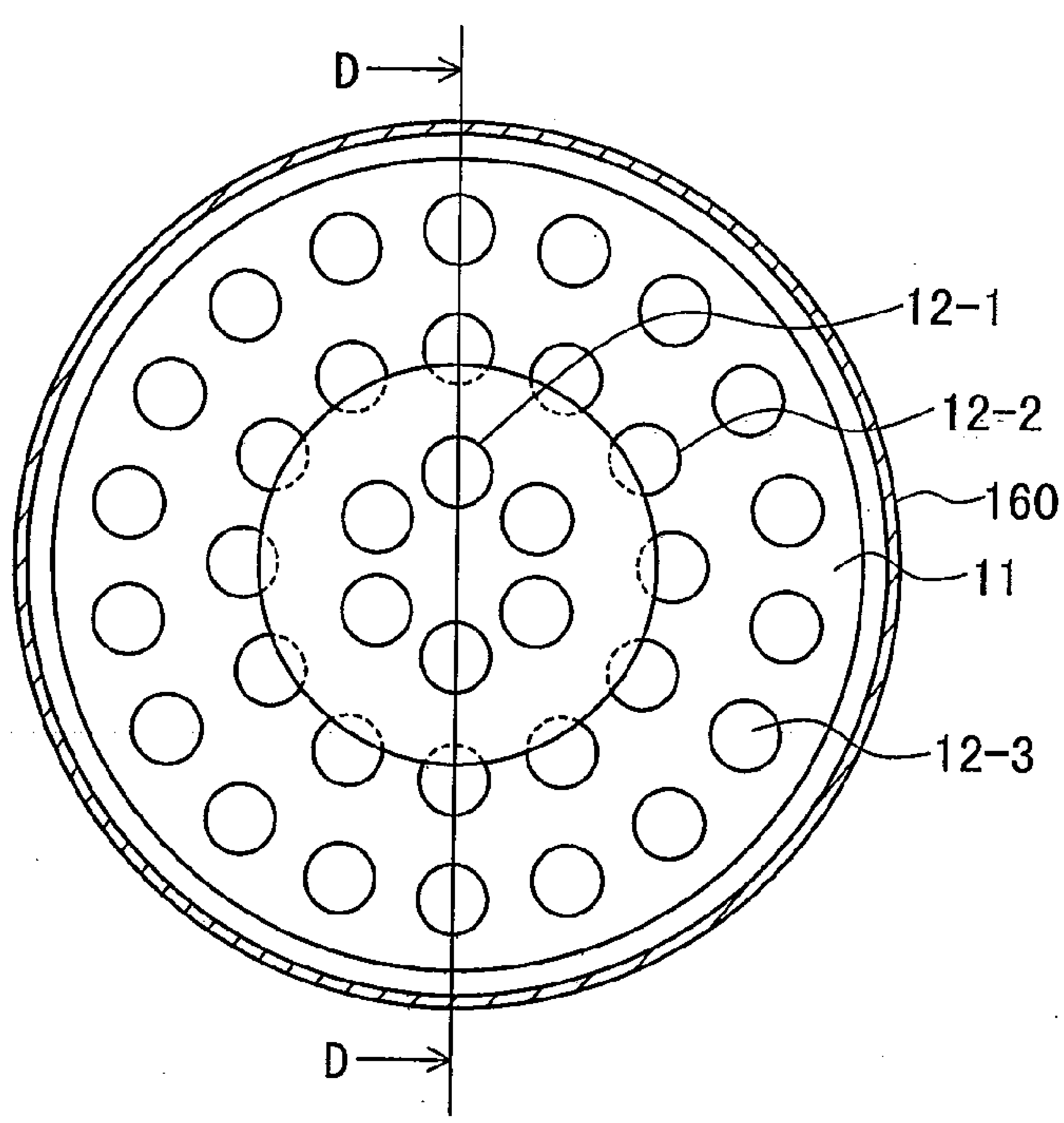


FIG.5A

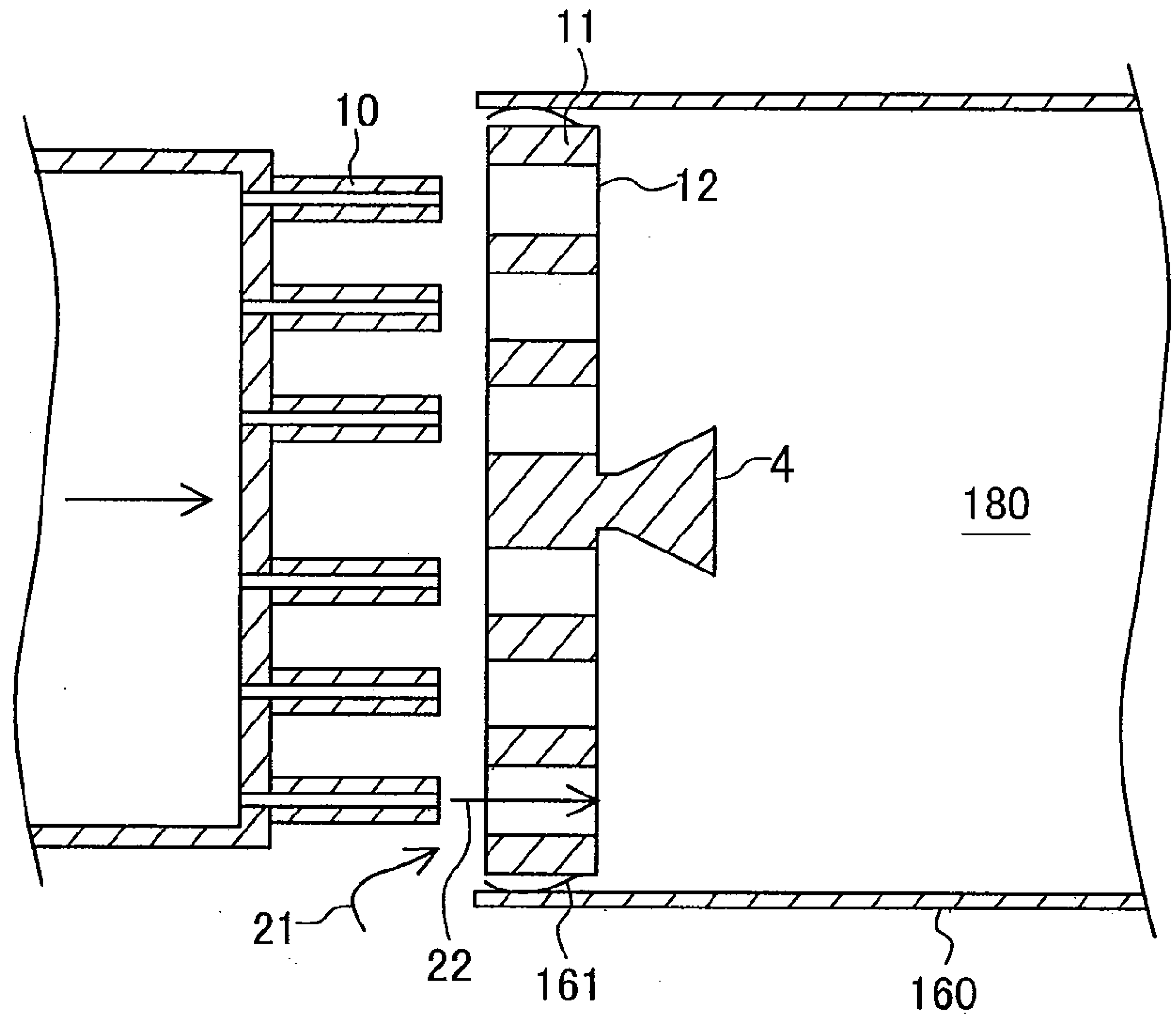


FIG.5B

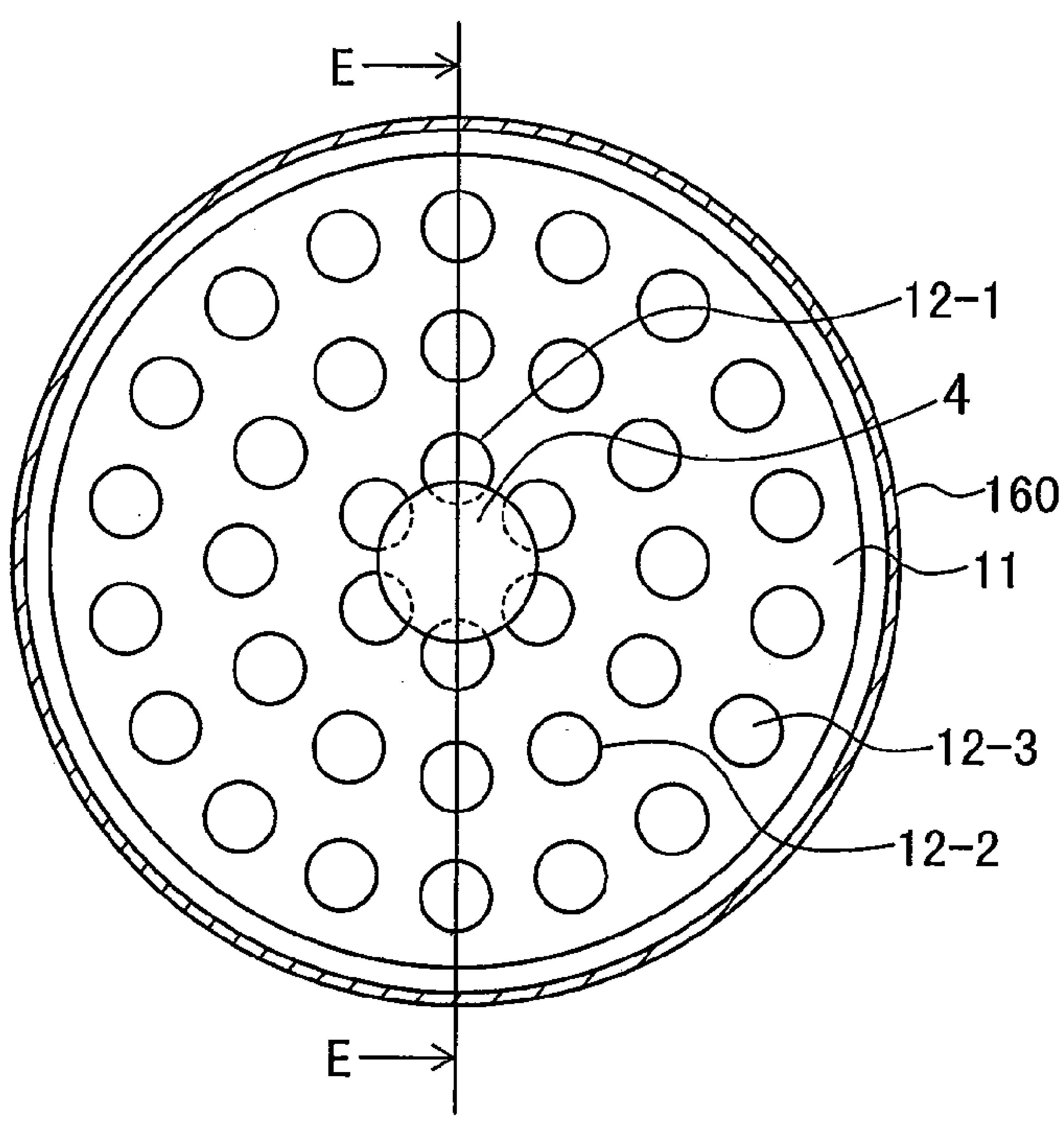


FIG.6A

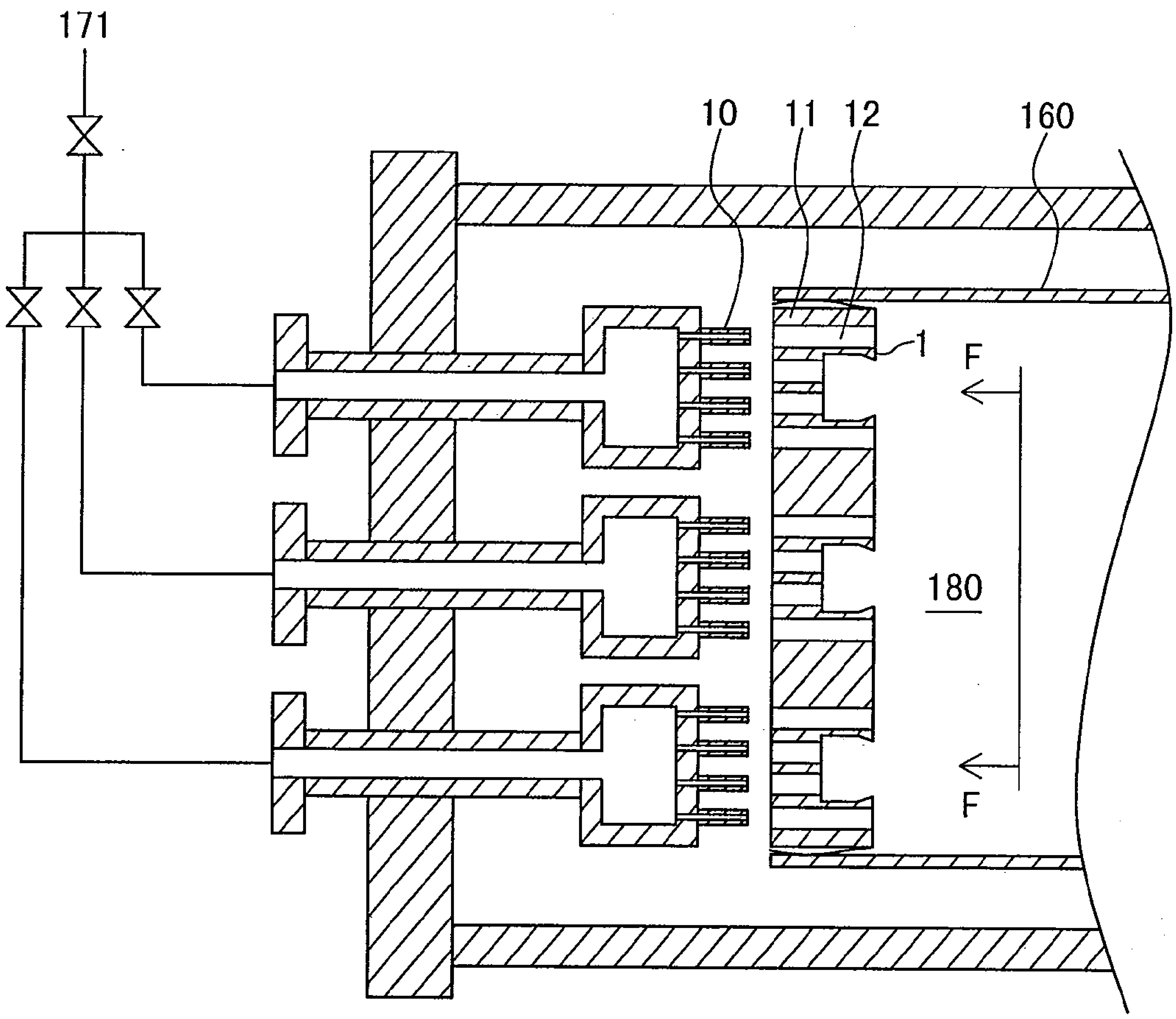


FIG.6B

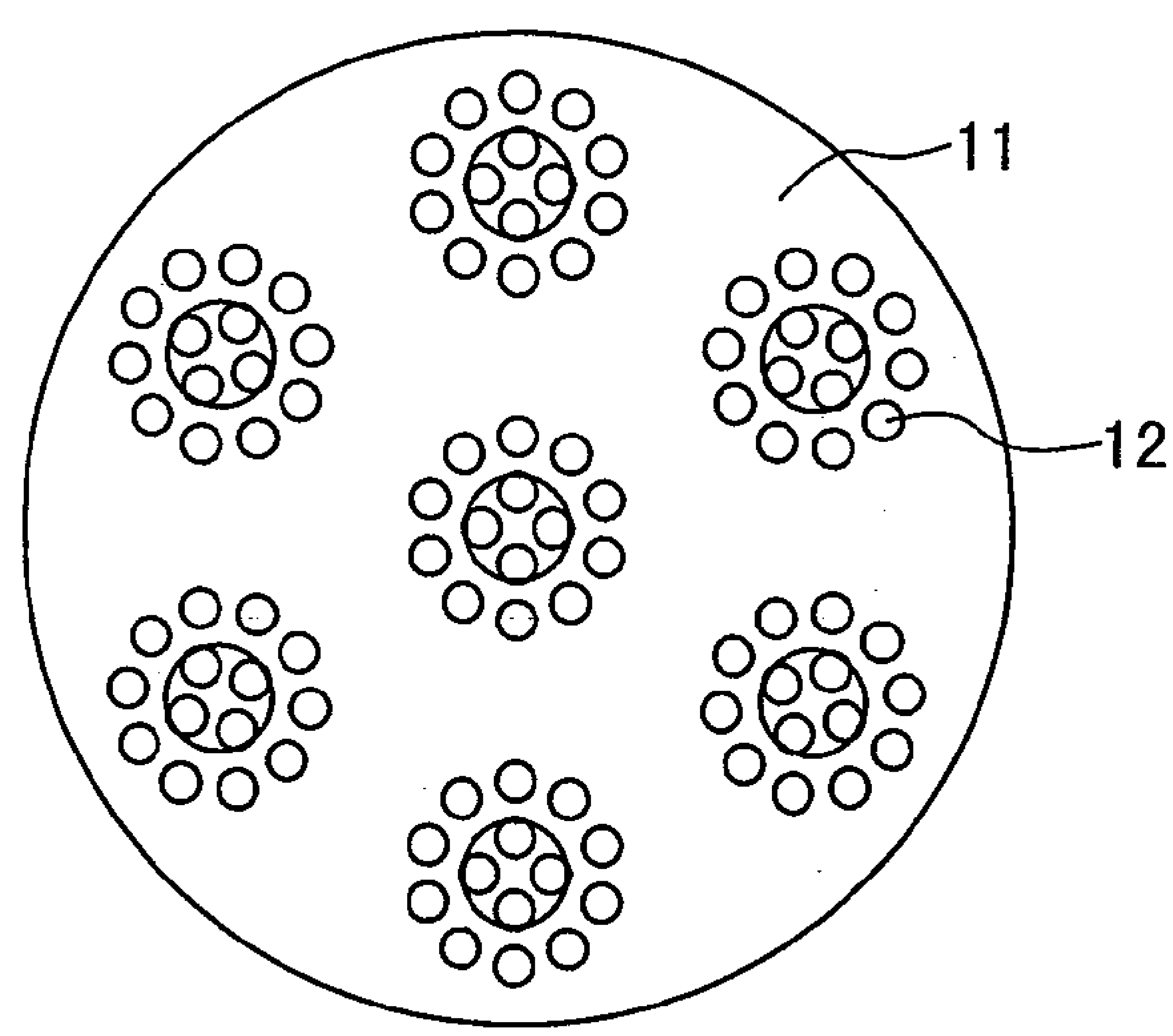


FIG.7

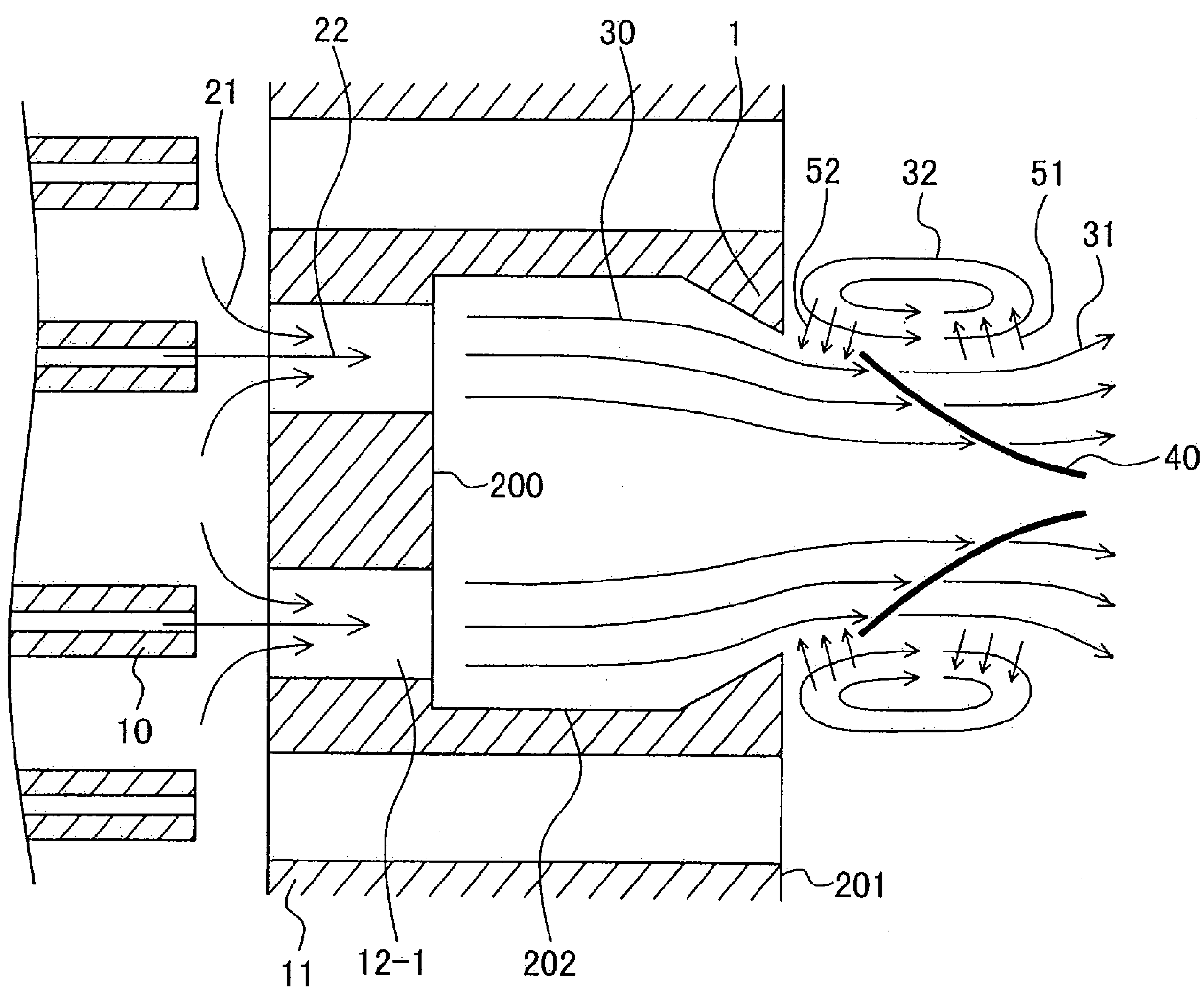


FIG.8A

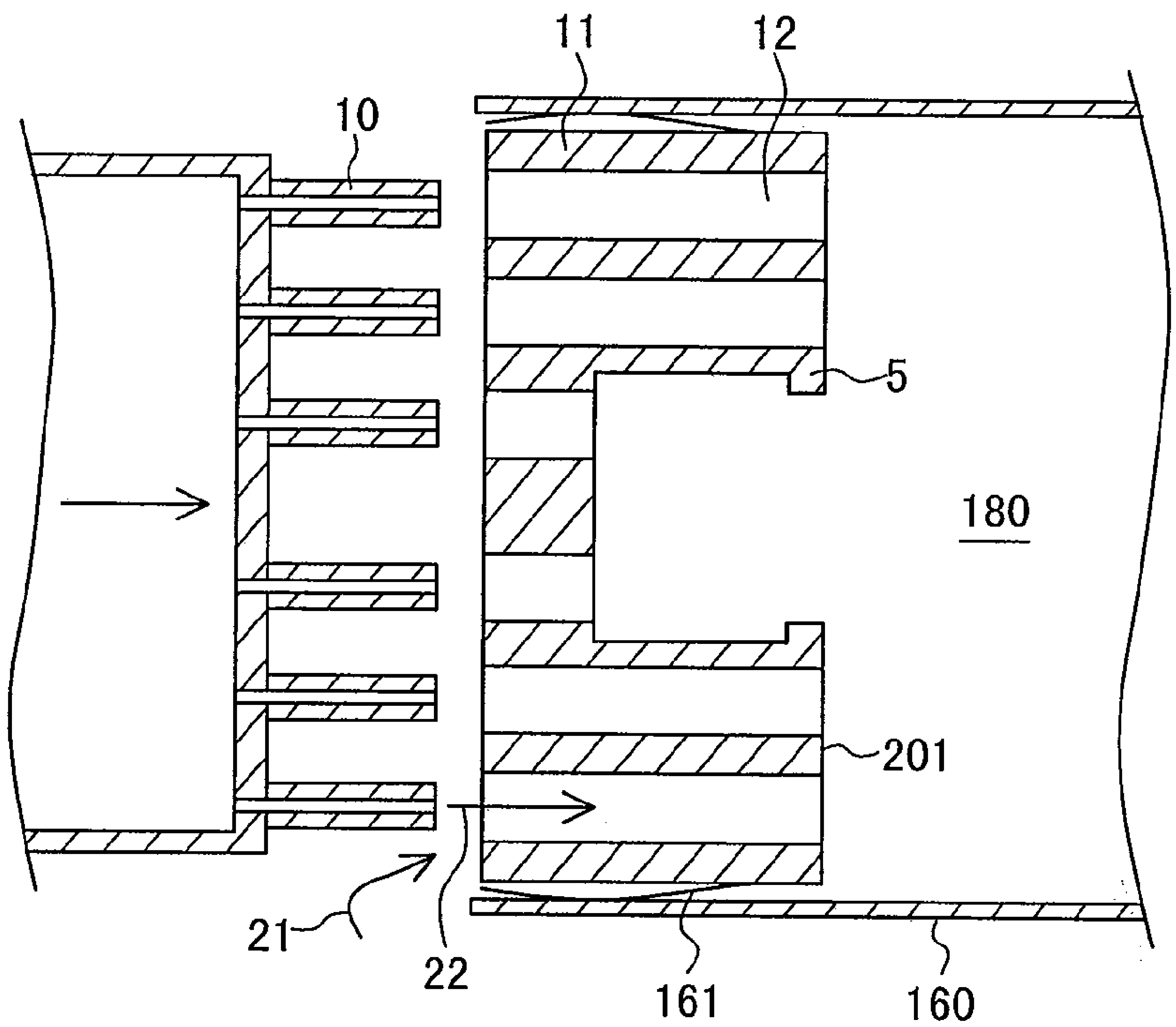


FIG.8B

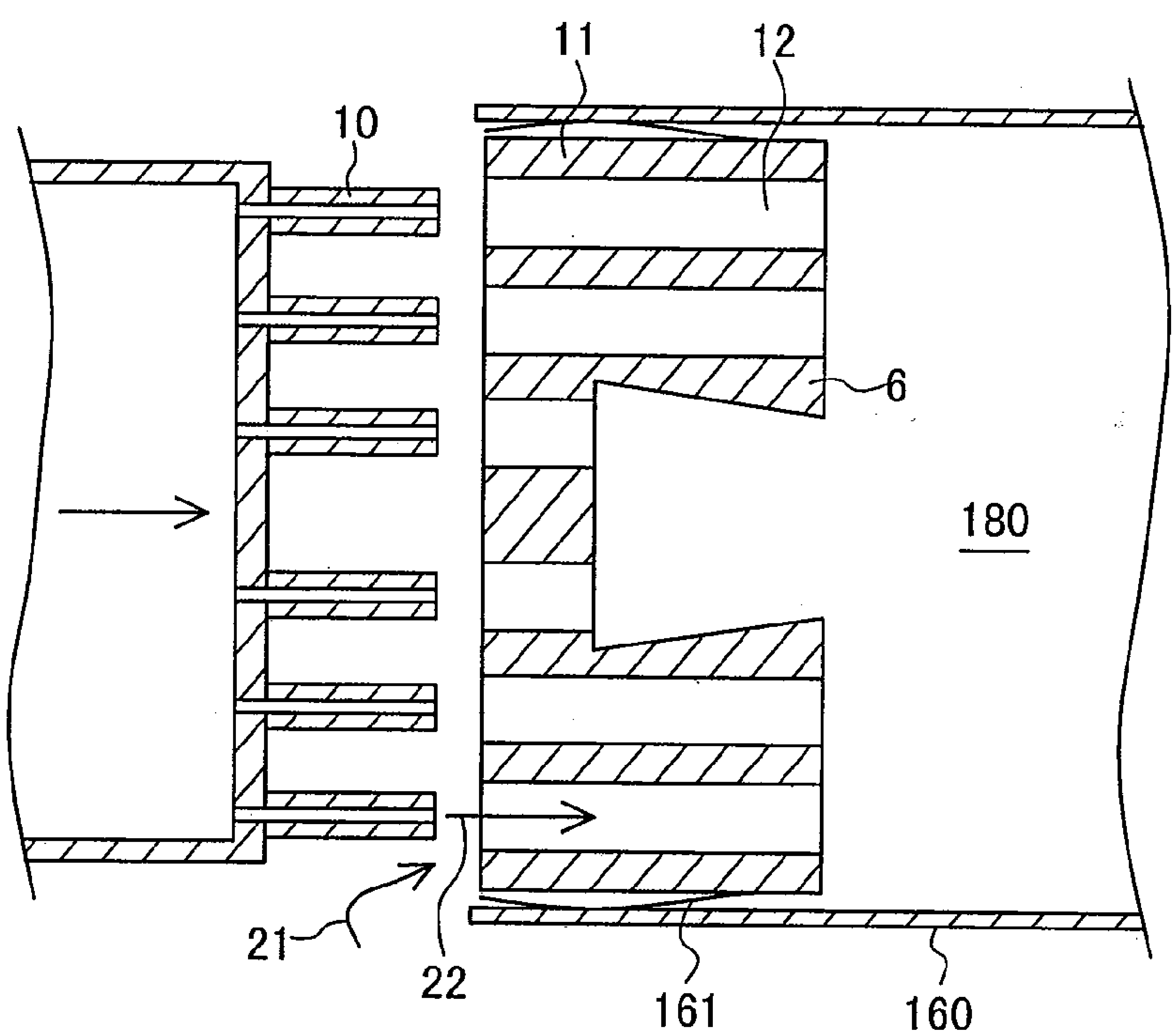


FIG.9

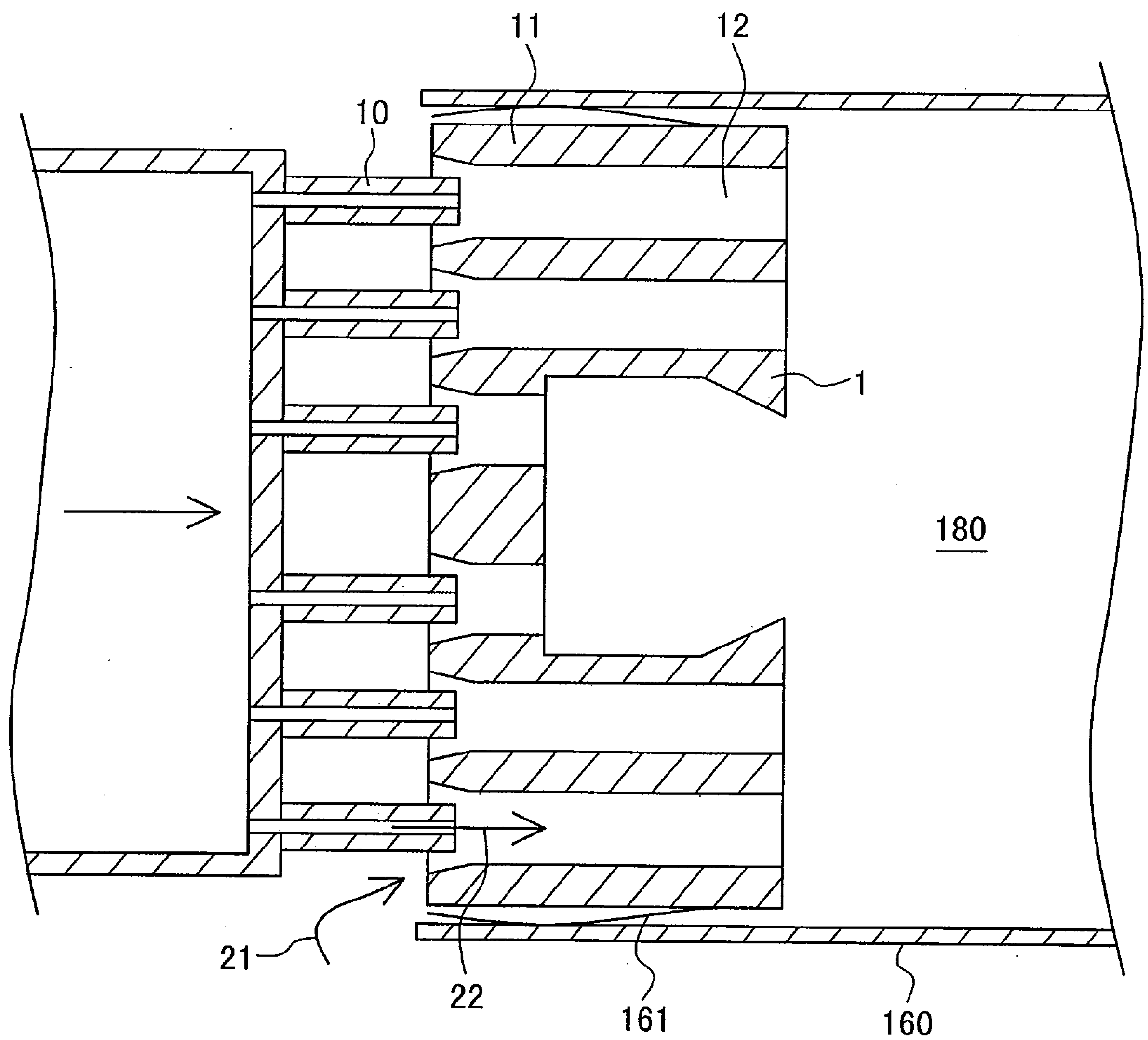


FIG.10A

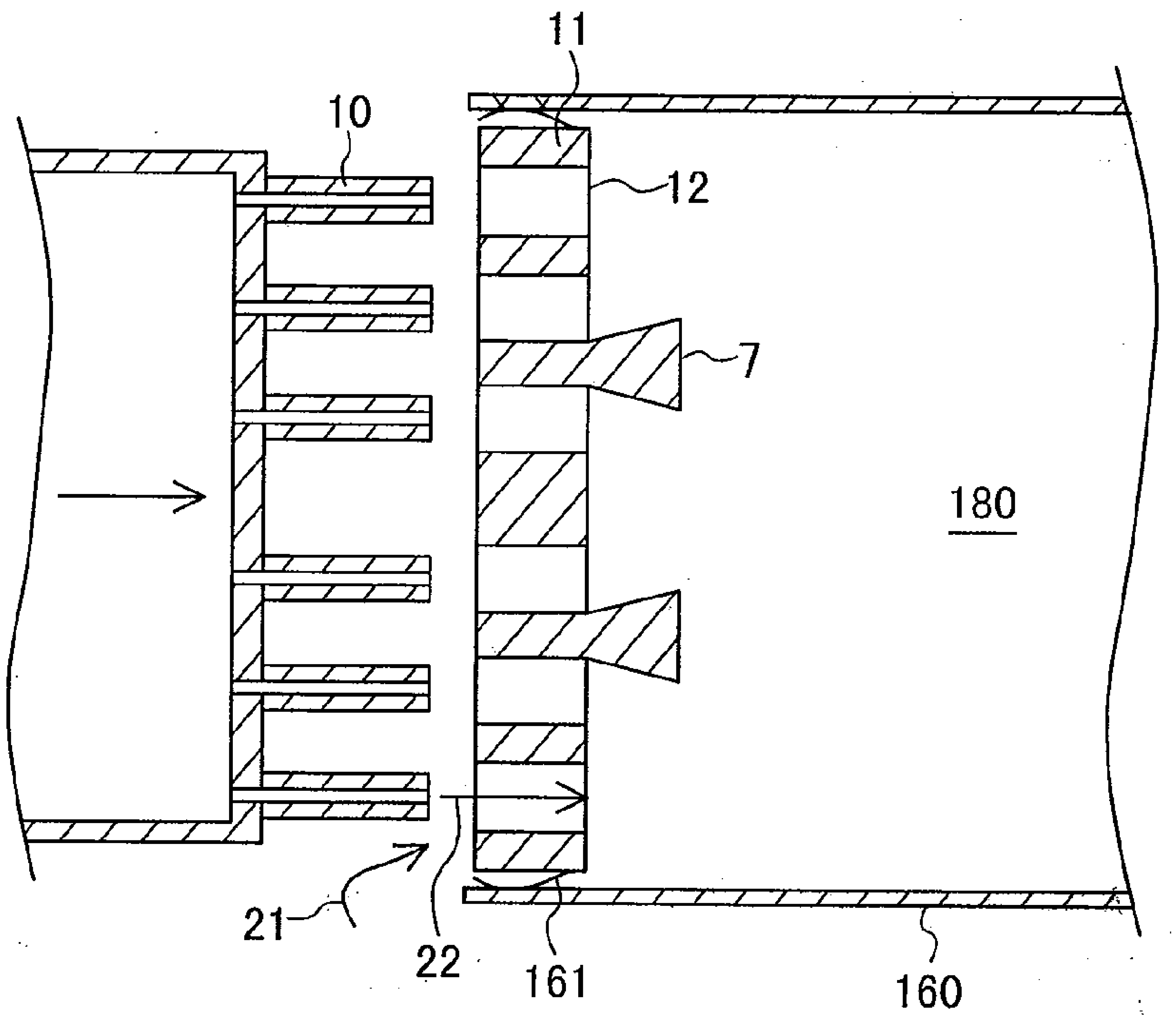


FIG.10B

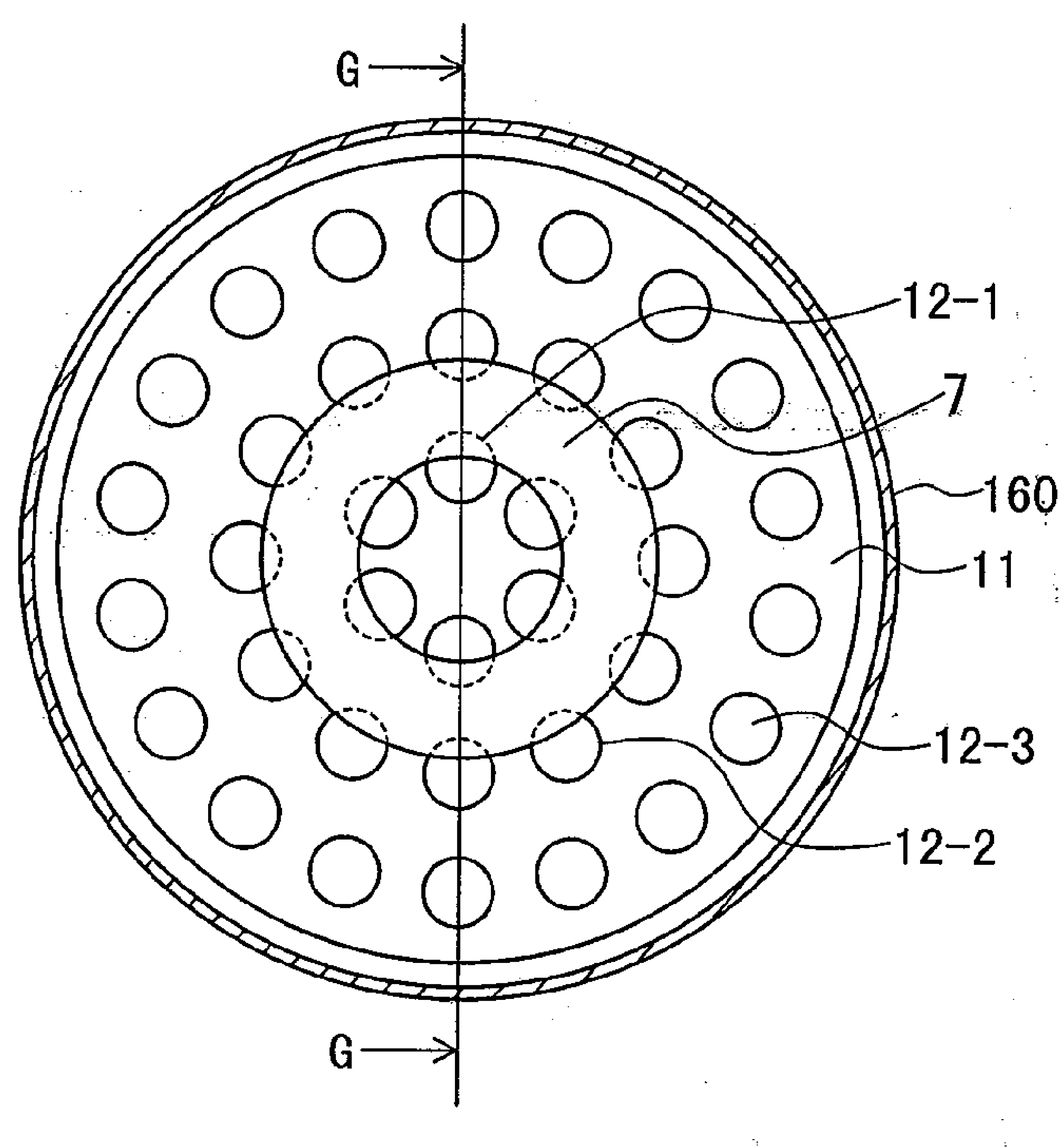


FIG.11

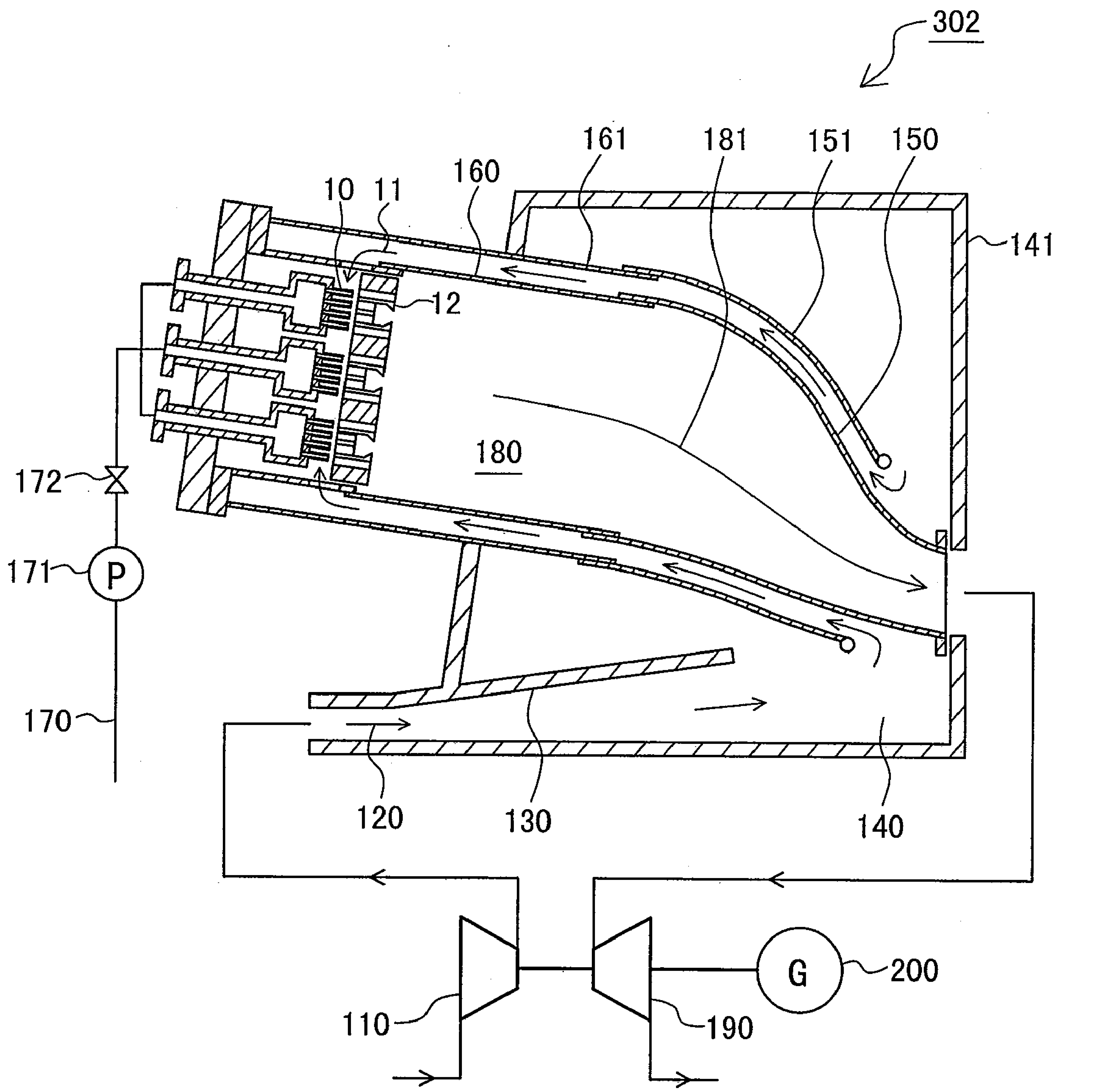

302
161
181
151
150
160
10
11
141
12
180
172
171
P
170
120
130
140
G
200
110
190

FIG.12

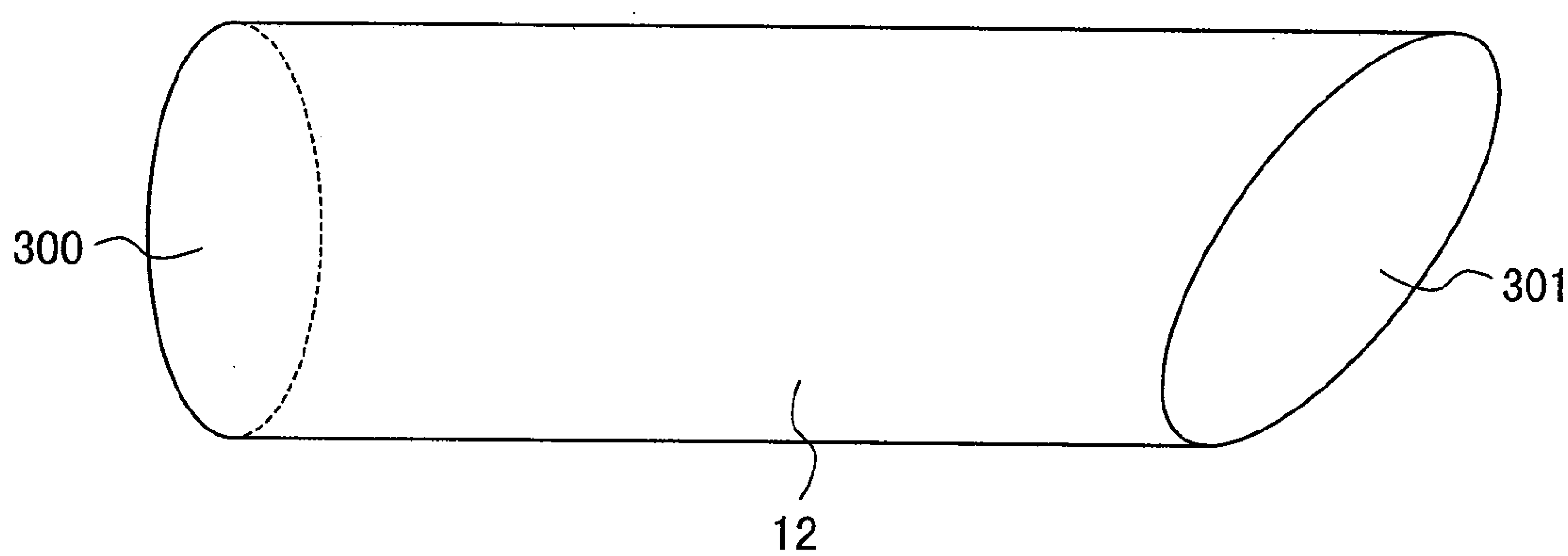


FIG.13

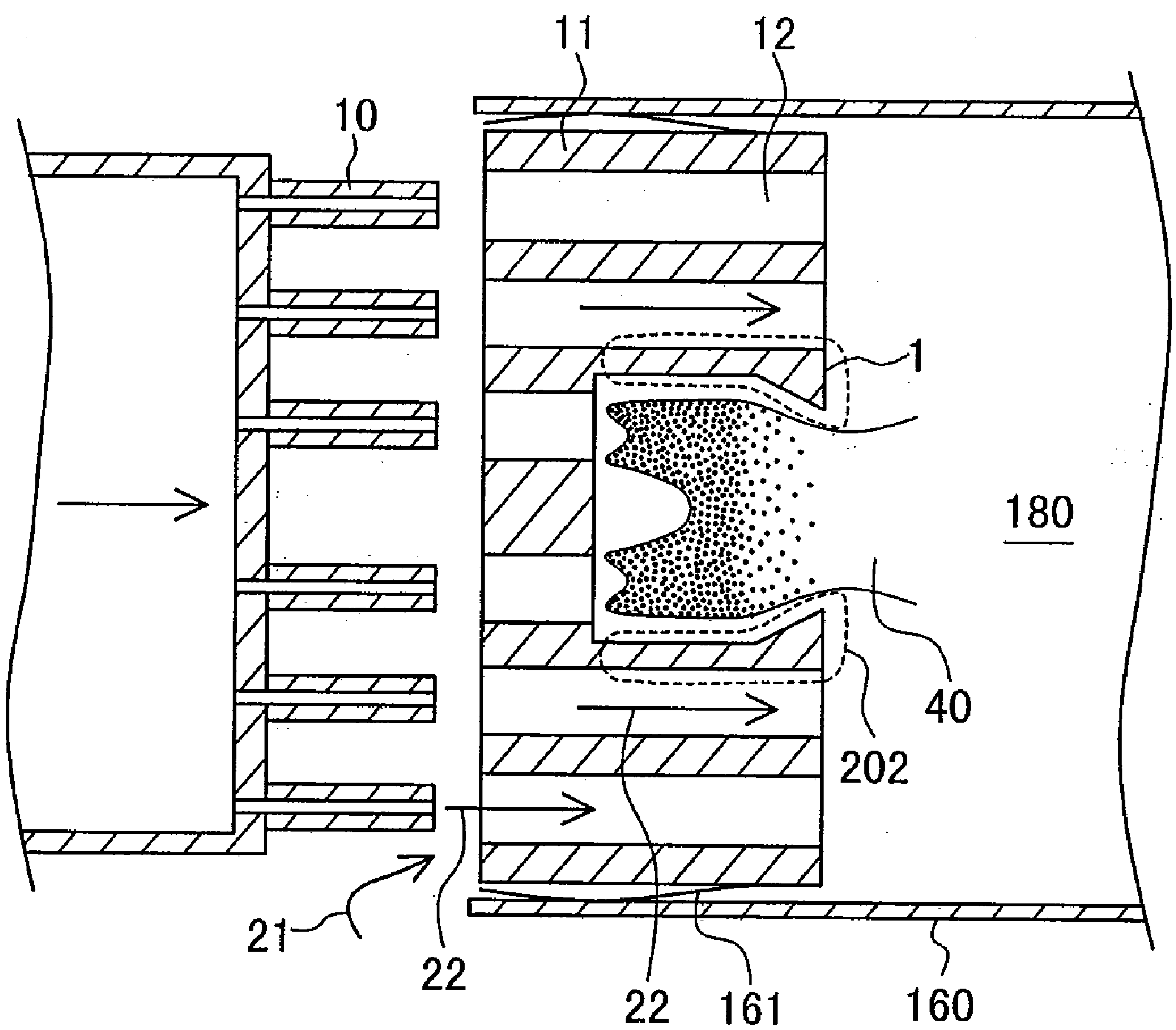


FIG.14A

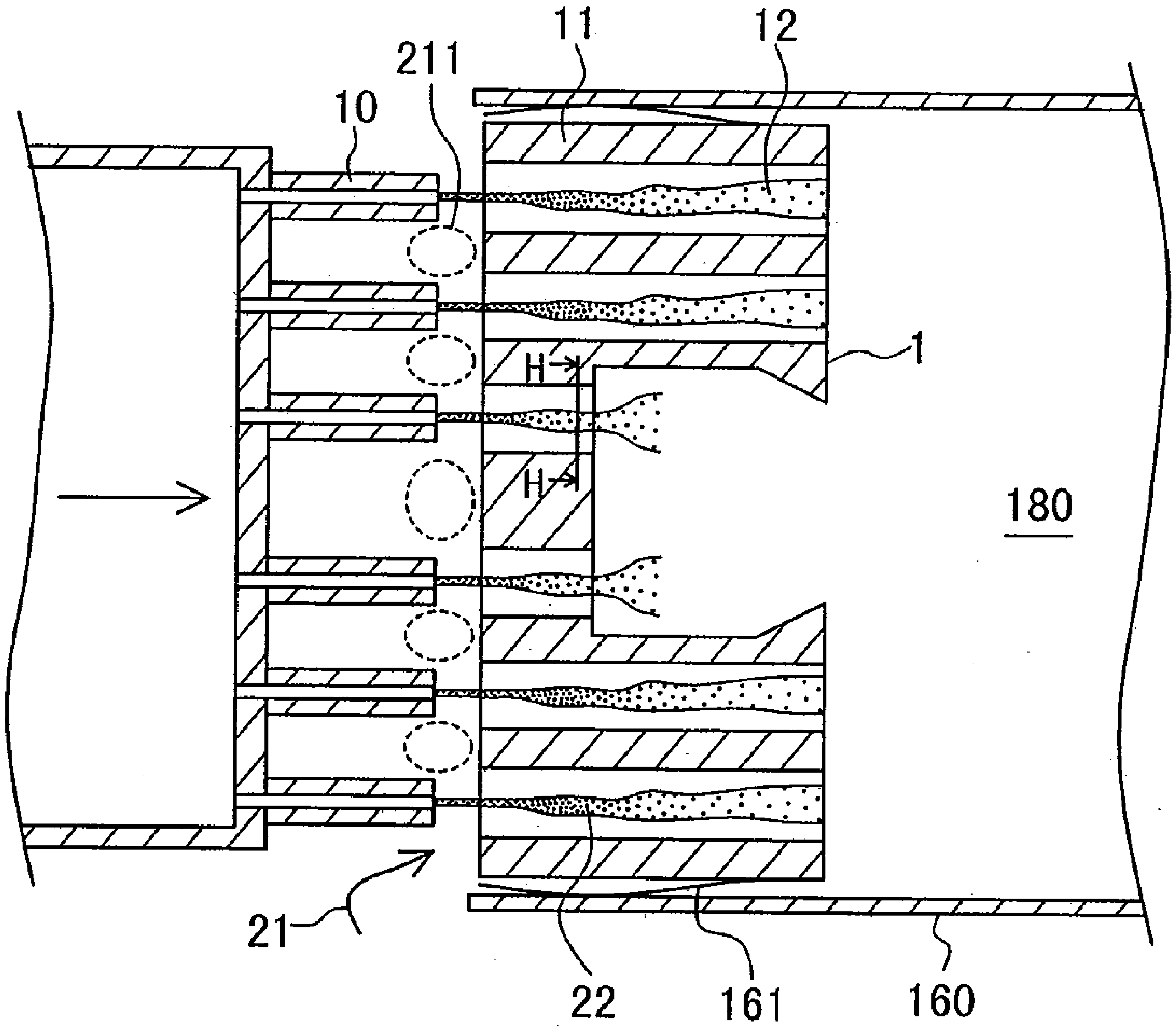
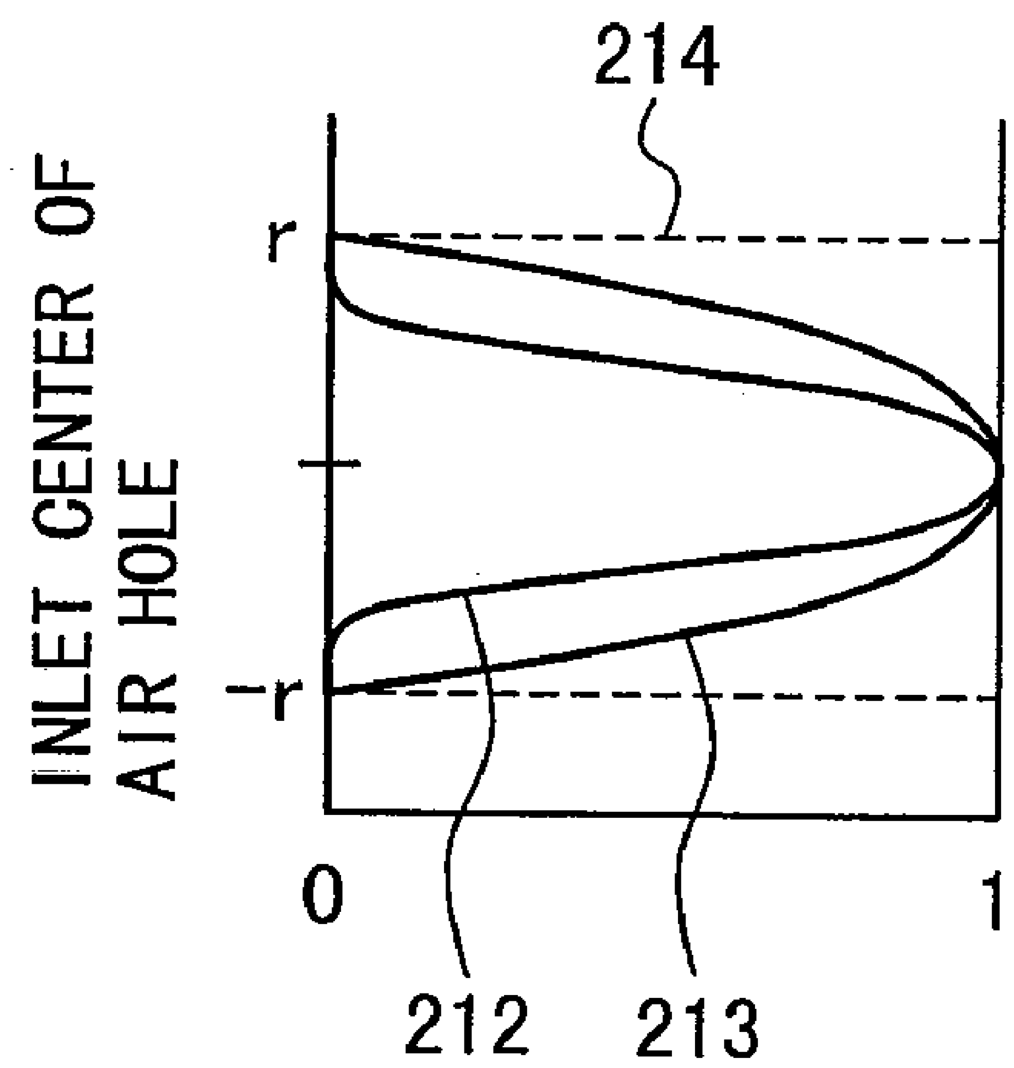


FIG.14B



COMBUSTION EQUIPMENT AND BURNER COMBUSTION METHOD

Background of the Invention

[0001] 1. Field of the Invention

[0002] The present invention relates to combustion equipment and to a burner combustion method.

[0003] 2. Description of the Related Art

[0004] Regulations on the emissions of air pollutants have been stringent in the recent years. For gas turbine combustors, for instance, various combustion schemes are under research to reduce the emission levels of nitrogen oxide (NOx) contained in exhaust gases.

[0005] One of these combustion schemes is a coaxial jet combustion scheme in which each of fuel nozzles and a corresponding one of air holes are arranged coaxially with each other and fuel and air are supplied to and burned in a combustion chamber. The coaxial jet combustion scheme can promote the mixing of fuel with air in a very short distance as compared with the conventional premixed combustion scheme so that it can reduce NOx emissions. See e.g. JP-A-2003-148734.

SUMMARY OF THE INVENTION

[0006] Combustion equipment of the coaxial jet combustion scheme can quickly mix fuel with air so that it can reduce NOx emissions. Hereafter it is required to further reduce NOx emissions.

[0007] NOx production exponentially increases as combustion gas temperature rises. To further reduce the NOx emissions, it is effective therefore to increase the mixing rate of fuel with air and concurrently to increase the flow rate of air relative to fuel, lowering combustion gas temperature in the combustion chamber.

[0008] However, if the operation is done under a lean fuel condition with a high ratio of air flow to fuel flow, flames become unstable. Thus, there is a limit to reduction in NOx emissions.

[0009] Accordingly, it is an object of the present invention to further reduce NOx emissions in combustion equipment of a coaxial jet combustion scheme.

[0010] According to an aspect of the present invention, there is provided combustion equipment including: a burner plate in which fuel and air are mixed with each other while the fuel and air pass through an air hole; a burner plate extension which is a portion of the burner plate and extends toward a combustion chamber side spaced apart from the air hole; and a protrusion disposed on the combustion chamber side of the burner plate extension so as to protrude in a direction where a flow of the fuel moves; wherein a gap between opposite portions of the protrusion is greater than a diameter of the air hole; and wherein a flame forming area is defined between the burner plate, the burner plate extension and the protrusion.

[0011] The combustion equipment of a coaxial jet combustion scheme according to the present invention can achieve a further reduction in NOx emissions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. **1**A is an enlarged schematic cross-sectional view illustrating fuel nozzles, air holes and their peripheral portions in a first embodiment, taken along line A-A of FIG. **1**B.

[0013] FIG. **1**B is a front view illustrating a burner plate in the first embodiment as viewed from a combustion chamber.

[0014] FIG. **2**A is an enlarged schematic cross-sectional view illustrating fuel nozzles, air holes and their peripheral portions in a second embodiment, taken along line B-B of FIG. **2**B.

[0015] FIG. **2**B is a front view illustrating a burner plate in the second embodiment as viewed from a combustion chamber.

[0016] FIG. **3**A is an enlarged schematic cross-sectional view illustrating fuel nozzles, air holes and their peripheral portions in a third embodiment, taken along line C-C of FIG. **3**B.

[0017] FIG. **3**B is a front view illustrating a burner plate in the third embodiment as viewed from a combustion chamber.

[0018] FIG. **4**A is an enlarged schematic cross-sectional view illustrating fuel nozzles, air holes and their peripheral portions in a fourth embodiment, taken along line D-D of FIG. **4**B.

[0019] FIG. **4**B is a front view illustrating a burner plate in the fourth embodiment as viewed from a combustion chamber.

[0020] FIG. **5**A is an enlarged schematic cross-sectional view illustrating fuel nozzles, air holes and their peripheral portions in a fifth embodiment, taken along line E-E of FIG. **5**B.

[0021] FIG. **5**B is a front view illustrating a burner plate in the fifth embodiment as viewed from a combustion chamber.

[0022] FIG. **6**A is an enlarged schematic cross-sectional view illustrating fuel nozzles, air holes and their peripheral portions in a sixth embodiment, taken along line E-E of FIG. **5**B.

[0023] FIG. **6**B is a front view illustrating a burner plate in the sixth embodiment as viewed from a combustion chamber.

[0024] FIG. **7** illustrates the states of thermal energy, air flow and fuel flow in the vicinity of a protrusion.

[0025] FIG. **8**A is an enlarged schematic cross-sectional view illustrating fuel nozzles, air holes and their peripheral portions in a modified example of the first embodiment.

[0026] FIG. **8**B is an enlarged schematic cross-sectional view illustrating fuel nozzles, air holes and their peripheral portions in another modified example of the first embodiment.

[0027] FIG. **9** is an enlarged schematic cross-sectional view illustrating fuel nozzles, air holes and their peripheral portions in another modified example of the first embodiment.

[0028] FIG. **10**A is an enlarged schematic cross-sectional view illustrating fuel nozzles, air holes and their peripheral portions in a modified example of the fifth embodiment, taken along line G-G of FIG. **10**B.

[0029] FIG. **10**B is a front view illustrating a burner plate in the modified example of the fifth embodiment as viewed from a combustion chamber.

[0030] FIG. **11** is a schematic view illustrating a configuration of a gas turbine.

[0031] FIG. **12** is a structural view of the air hole in the third embodiment.

[0032] FIG. **13** illustrates flames propagating upstream of the protrusion in the burner plate of the first embodiment.

[0033] FIG. **14**A illustrates a state where fuel flow jetted from fuel nozzles moves into a combustion chamber in the burner plate of the first embodiment.

[0034] FIG. **14**B is a diagram illustrating a fuel concentration distribution and a velocity distribution at an H-H cross-section of FIG. **14**A.

[0035] **1-7** . . . protrusions

[0036] **10** . . . fuel nozzle

[0037] **11** . . . burner plate

[0038] **12** . . . air holes

[0039] **21** . . . air flow

[0040] **22** . . . fuel flow

[0041] **30** . . . premixed gas

[0042] **31** . . . burned gas

[0043] **32** . . . circulating flow

[0044] **40** . . . flame

[0045] **51**, **52** . . . thermal energy

[0046] **110** . . . air compressor

[0047] **120** . . . high-pressure air

[0048] **180** . . . combustion chamber

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0049] FIG. **11** is an entire schematic view of a gas turbine in which a coaxial jet combustion scheme is applied to a gas turbine combustor which is one of combustion equipment.

[0050] The gas turbine includes an air compressor **110**, combustion equipment **302** and a turbine **190**.

[0051] The air compressor **110** compresses external air to generate high-pressure air **120**, which is introduced from a diffuser **130** to a plenum chamber **140**. The high-pressure air **120** flows in a gap defined between a transition piece **150** and a transition piece flow sleeve **151** externally installed around the transition piece **150** and then flows in a gap defined between a liner **160** and an outer casing **161** coaxially externally installed around the liner **160**. The transition piece **150** is joined to the liner **160** and the transition piece flow sleeve **151** is joined to the outer casing **161**. After flowing through the gap, the high-pressure air **120** reverses the course and enters a combustion chamber **180** from air holes **12** provided in a burner plate **11**.

[0052] On the other hand, in a fuel system **170**, fuel is increased in pressure by a fuel pump **171** and regulated in flow rate by a flow regulating valve **172**. The fuel is jetted from each of fuel nozzles **10** toward a corresponding one of the respective inlet portions of the air holes **12**. In this case, each of the fuel nozzles **10** and a corresponding one of the air holes **12** are arranged coaxially with each other. "The coaxial arrangement" refers to a configuration in which the fuel nozzles **10** and the burner plate **11** having the air holes **12** located on the downstream side of the fuel nozzles **10** are arranged such that fuel is jetted from the fuel nozzles **10** toward the approximate center of the air hole inlet surface to form air flow on the outer circumferential side of fuel flow in the inside of the air holes **12**. In addition, "coaxial jet flow" refers to jet flow in which annulus air flow is formed on the outer circumferential side of the fuel flow in the inside of the air holes **12**.

[0053] The fuel flow and air flow jetted from the air holes **12** are fed to the combustion chamber **180** inside the liner **160** and burn to form flames, thereby generating high-temperature and high-pressure combustion gas **181**. The combustion gas **181** generated in the combustion equipment **302** is led from the transition piece **150** to the turbine **190**.

[0054] The high-temperature and high-pressure combustion gas **181** rotates a turbine shaft in the turbine **190**, so that the generator **200** coupled to the turbine shaft generates output power from the combustion gas **181**. The air compressor **110** and the generator **200** are connected to the turbine **190** via a single shaft. However, the air compressor **110**, the turbine **190** and the generator **200** may be of two-shaft configuration.

[0055] The fuel system **170** is a single system in FIG. **11**. A multi-burner structure may be applicable in which a fuel system is divided into multiple subsystems, which feed fuel to a plurality of fuel headers. For example, gas turbines widely used in generating power plants or the like are such that a plurality of burners are radially arranged for a turbine shaft.

[0056] The coaxial jet combustion scheme described above can suppress NOx emissions to low levels. However, since the environmental limit of the NOx emissions becomes stricter year by year, also the coaxial jet combustion scheme is desired to further reduce the NOx emissions.

[0057] NOx production exponentially increases as combustion gas temperature rises. To further reduce the NOx emissions, it is necessary therefore to increase the mixing rate of fuel with air and simultaneously to increase the flow rate of air relative to fuel, lowering combustion gas temperature in the combustion chamber. However, if the operation is done under a lean fuel condition, flames become unstable. To reduce the NOx emissions in the coaxial jet combustion scheme, thus, it is necessary to improve the flame stability in the combustion equipment.

EMBODIMENT 1

[0058] FIG. **1**B is a front view of a burner plate **11** as viewed from a combustion chamber **180**. FIG. **1**A is an enlarged schematic cross-sectional view taken along line A-A of FIG. **1**B, illustrating fuel nozzles **10**, air holes **12** and their peripheral portions in the entire gas turbine schematically shown in FIG. **11**.

[0059] A burner of the first embodiment includes the fuel nozzles **10**; the burner plate **11** having the air holes **12**; a protrusion **1** formed on the burner plate **11**; and a liner **160** defining the combustion chamber **180**. A spring seal **161** is provided between the burner plate **11** and the liner **160**.

[0060] Fuel flow **22** is jetted from the fuel nozzle **10** toward the inlet portion of the air hole **12**. Air flow **21** enters the inlet portion of the air hole **12** from the outer circumferential side of the fuel nozzle **10**. The air flow **21** having entered the air holes **12** passes through the inside of the air hole **12** so as to encircle the fuel flow **22** from the outer circumferential side thereof, and jet out from the air hole **12** to the combustion chamber **180**. The coaxial jet flow composed of the fuel flow and air flow jets out from the outlet portion of the air hole **12** and forms flames in the combustion chamber **180**. The inlet portion of the air hole **12** is located at a position opposed to the jet port of the fuel nozzle **10**. In addition, the outlet port of the air hole **12** faces the combustion chamber **180**.

[0061] The air holes **12** are formed in the burner plate **11**. As shown in FIG. **1**B, the air holes **12** are arranged to form three coaxial circular rows: six, twelve and eighteen air holes **12** from the inner circumferential side of the burner. These three air hole circular rows are referred to as a first circular row air holes **12-1**, a second circular row air holes **12-2** and a third circular row air holes **12-3** from the inner circumferential side of the burner. Thus, one burner plate is configured as shown in FIG. **1**B.

[0062] The burner plate **11** is formed such that the inner circumferential side (the axial center side) of the burner is thinner than the outer circumferential side thereof. Specifically, a portion (on the outer circumferential side) of the burner plate **11** is formed as a burner plate extension which extends toward the combustion chamber side spaced apart from the first circular row air holes **12-1**. Changing the thickness of the burner plate **11** as described above can allow the outlet portions of the air holes **12** to positionally differ from each other in the burner-axial direction.

[0063] As shown in FIG. **1**A, the burner plate **11** has such a steplike shape as to form a recessed area **200** on the burner-axial center side. The outlet portions of the six air holes **12-1** (the first circular row) provided on the burner-axial center side are disposed in the recessed area **200**. The outlet portions of the second- and third-circular row air holes **12-2**, **12-3** are disposed at a steplike area **201** of the burner plate **11** formed with a step as against the recessed area **200**.

[0064] The burner plate **11** is provided with a lateral surface portion **202** as a plane that connects the recessed area **200** with the steplike area **201**.

[0065] The recessed area **200** is shaped in a circle with respect to the burner-axial center. The lateral surface portion **202** is shaped such that a cylindrical column is hollowed out from the burner plate **11**. Thus, the steplike shape of the burner plate **11** is formed to continue in the circumferential direction. In the present embodiment, the steplike shape of the burner plate **11** is used to provide the protrusion **1** on the downstream side of the lateral surface portion **202** of the burner plate **11**. In addition, the protrusion **1** is located on the combustion chamber side of the burner plate extension so as to protrude in a direction perpendicular to the passing direction of the fuel flow and air flow so that the fuel flow and air flow jetted from the first circular row air holes **12-1** may collide with the step of the burner plate **11**. The gap between the opposite portions of the protrusion **1** is greater than the diameter of the air hole. If the burner plate is cut vertically with respect to a plane formed by the steplike area **201** of the burner plate **11**, the edge of the protrusion **1** is sharply angled. Also the protrusion **1** is formed to continue in the circumferential direction as with the steplike shape of the burner plate **11**.

[0066] As shown in FIG. **1**B, the protrusion **1** provided on the lateral surface portion **202** of the burner plate **11** is provided to partially obstruct the fuel flow and air flow jetted from the first circular row air holes **12-1**, that is, plays a role of an obstacle to disturb the fuel flow and air flow. High-temperature recirculation flow is formed on the downstream side of the protrusion **1**. This recirculation flow serves as a flame source, which applies thermal energy to unburned premixed gas for ignition. Thus, the flame stability of the entire burner is enhanced. Consequently, it is possible to operate under the leaner fuel condition, thereby enabling reduced NOx emissions.

[0067] The mechanism of the flame stability enhancement is described with reference to FIG. **7**, which illustrates a state of thermal energy and flow with respect to the protrusion **1** and to the first circular row air holes **12-1**.

[0068] The fuel flow jetted from the fuel nozzles **10** enters a corresponding one of the first circular row air holes **12-1**. Coaxial jet flow in which air flow is formed on the outer circumferential side of fuel flow inside the air holes **12-1** moves to the downstream side and simultaneously premixing progresses. The premixed gas **30** of the air flow **21** with fuel flow **22** jetted from the first circular row air holes **12-1** jets out to a space defined by the recessed area **200** and lateral surface area **202** of the burner plate **11**. Then, the premixed gas **30** jetted from the space forms flames **40**, that is, becomes high-temperature burned gas **31**, in the combustion chamber **180**. In this way, the space defined by the burner plate, burner plate extension and protrusion serves as a zone adapted to form the flame source.

[0069] The premixed gas **30** jetted from the air holes **12-1** flows downstream along the lateral surface area **202** of the burner plate **11**. The flow direction of the premixed gas **30** is internally bent by the sharply-angled protrusion **1** provided on the downstream side of the lateral surface area **202**. Consequently, negative pressure occurs on the downstream side of the protrusion **1**, whereby recirculation flows **32** are formed that move from the downstream side of the burned gas **31** to the upstream side which is in the negative pressure state. It is probable that the recirculation flows **32** serve to receive thermal energy **51** from the high-temperature burned gas **31** and apply thermal energy **52** to the unburned premixed gas **30**. The premixed gas **30** can form the flames **40** by obtaining the thermal energy **51** required for ignition. Since the thermal energy **52** is continuously applied to the premixed gas **30**, the premixed gas **30** tends to ignite, which improves an ignition characteristic. Since the premixed gas **30** easily ignites at the protrusion **1**, flame stability at the central portion of the burner is improved and the flames at the central portion of the burner are used as a flame source to also improve the flame stability at the outer circumferential portion of the burner. As a result, the flame stability of the entire burner is improved. Operation can be done under the leaner fuel condition by increasing a ratio of an air flow rate to a fuel flow rate. It is possible thus to further reduce the NOx emissions from the combustion equipment.

[0070] As shown in FIG. **8**A, the protrusion **1** may not be shaped in a sharply-angled triangle but may be a protrusion **5** shaped in a square in cross-section. This simplifies the manufacture of the protrusion **5**, which leads to reduced manufacturing cost.

[0071] In addition, a protrusion **6** may gently be inclined in cross-section as shown in FIG. **8**B. This inclined protrusion **6** is provided with inclination extending along the entire lateral surface portion **202**. In the case where the protrusion (flame stabilizer) is used to stabilize flames, if disturbance (secondary flow) may occur on the upstream side of the protrusion, it is probable that the flames reach the upstream side of the protrusion through the low flow velocity portion of the disturbance. In such a case, the protrusion (flame stabilizer) may be burn out. However, since the protrusion **6** is gently inclined in cross-section as shown in FIG. **8**B, it is possible to suppress the disturbance occurring on the upstream side of the protrusion **6** and prevent the burnout of the protrusion **6**.

[0072] FIG. **13** illustrates the behavior of flames **40** propagating to the upstream side of the protrusion **1** if the burner plate of the present embodiment is used. A wall surface of the lateral surface area **202** in contact with the flames **40** is heated by the flames **40**. If not cooled, the protrusion **1** may be melted. To prevent the protrusion from being melted, the protrusion **1** is cooled by air and fuel much lower in temperature than the flames by allowing the fuel flow **22** and air flow **21** to move in the air holes **12** of the burner plate extension. If the fluid cooling the protrusion **1** is fed from a portion other than the air holes, the configuration of flow paths is complicated. However, the protrusion **1** can be prevented from being burn out with a simplified configuration by allowing fuel and air to flow in the air holes provided in the burner plate extension.

[0073] To explain the function and effect of the present invention, a description is next given of differences between a premixer provided with a recess type flame stabilizer (a comparative example) and the present invention. In the comparative example, the premixer has annular flow passages provided on the outer circumferential side of the pilot burner. In addition, the recess type flame stabilizer is provided at the outlet portion of the premixer. In such a comparative example, the premixer is internally joined together and filled with premixed gas. If flames propagate to the upstream side of the recess type flame stabilizer, it is probable that the flames propagate inside the premixer at a burst to melt the flame stabilizer.

[0074] In contrast to such a comparative example, the present invention is such that the air holes **12** are configured between the protrusion **1** and the fuel nozzles **10** so as to be separate from one another. FIG. **14**A illustrates fuel flows jetted from the fuel nozzles to the combustion chamber. In the present invention, two air holes **12** communicate with each other through one space upstream thereof (on the left in FIG. **14**A) and the fuel flow **22** is jetted from the fuel nozzle **10** to the inlet center of the corresponding air hole **12**. Thus, on the upstream side of the inlet surface of the air hole **12**, the fuel flow jetted from the fuel nozzle **10** is prevented from mixing with the air flow. When entering the air hole **11**, the fuel flow **22** mixes with the air flow around thereof while gradually diffusing. That is to say, no fuel exists in the space **211** on the upstream side of the inlet surface of the air hole **11** and between the adjacent air holes. Thus, even if flames in some air holes **11** propagate to the upstream side, it is possible to prevent the flames from propagating to the next air hole.

[0075] The arrangement relationship between the burner plate **11** and the fuel nozzles **10** is such that fuel and air are mixed with each other while the fuel and air pass through the air holes **12**. This arrangement relationship has a characteristic of preventing flames entering the air holes and much higher reliability than that of the premixer of the comparative example. FIG. **14**B illustrates a fuel concentration distribution **212** and a velocity distribution **213** at an H-H cross-section of FIG. **14**A. The longitudinal axis represents the coordinates of the air hole inlet surface and a radius of the air hole inlet is indicated with symbol r. In addition, the horizontal axis represents a relative value between the fuel concentration and velocity. A broken line **214** indicates the position of the air hole wall surface. As shown in the figures, the velocity of a flowing fluid is reduced in the vicinity of the wall surface **214** because of the influence of wall surface shearing stress. For this reason, it is probable that flames enter the inside of the air hole through a slow-velocity area. However, because of the arrangement relationship between the burner plate **11** and the fuel nozzle **10** in the present invention, the fuel concentration distribution **212** is very low in a slow-velocity area close to the wall surface. Because of the quenching effect resulting from drawing heat from the wall surface, flames will not propagate in the area close to the air hole wall surface. Thus, since the protrusion is provided in the direction where the fuel flow jetted from the air holes **12** moves, it is possible to prevent the flames from propagating to the fuel jet hole of the fuel nozzle **10** even if the flames propagate to the upstream side of the protrusion. In this way, the protrusion can stabilize the flames and a satisfactory effect of anti-backfire can be provided.

[0076] Further, it is desirable that a fuel nozzle be inserted into an associated air hole. The insertion of the fuel nozzle into the air hole can improve the mixing rate of fuel with air. Thus, as shown in FIG. **9**, the insertion of the fuel nozzle **10** into the air hole **12** can concurrently achieve further improvement of the mixing rate and the improvement of flame stability.

[0077] It is effective to the central axis of the air hole **12** is inclined with respect to the central axis of the burner. In particular, the air hole **12** is slantly arranged so that the fuel flow and air flow jetted from the air hole **12** may have a velocity component swirling with respect to the central axis of the burner. This makes it possible to further improve flame stability.

EMBODIMENT 2

[0078] FIG. **2**B is a front view illustrating a burner plate **11** as viewed from a combustion chamber **180**. FIG. **2**A is an enlarged schematic cross-sectional view illustrating fuel nozzles **10**, air holes **12** and their peripheral portions in the entire gas turbine of FIG. **11**, taken along line B-B of FIG. **2**B.

[0079] In the first embodiment, the flames formed by the first circular row air holes **12-1** are stabilized to thereby improve the stability of the flames formed by the second and third circular row air holes **12-2**, **12-3**. In contrast to this, in a second embodiment, a protrusion **2** is provided for also the second circular row air holes **12-2** to improve the stability of the flames formed by the second circular row air holes **12-2**. Consequently, the flame stability of the entire burner can be further enhanced.

[0080] The basic mechanism of the flame stability improvement is similar to the contents described with FIG. **7**. Specifically, high-temperature recirculation flow is formed not only on the burner inner circumferential side (the first circular row air holes **12-1**) but also on the burner outer circumferential side (the second circular row air holes **12-2**). This recirculation flow serves as a flame source and thermal energy is applied to premixed gas jetted from the second circular row air holes, thereby improving the ignition characteristic.

[0081] In FIGS. **2**A and **2**B, the two protrusions are provided. However, three, four or more protrusions may be provided depending on the number and arrangement of air holes.

[0082] The protrusions of the second embodiment may be sharply-angled in cross-section; however, it may be formed rectangular in cross-section in view of fabrication. Further, the protrusion may be gently inclined in cross-section.

[0083] In addition, in the second embodiment, the insertion of the fuel nozzle into the air hole can concurrently achieve the further improvement of the mixing rate and the improvement of flame stability.

EMBODIMENT 3

[0084] FIG. **3**B is a front view illustrating a burner plate **11** as viewed from a combustion chamber **180**. FIG. **3**A is an enlarged schematic cross-sectional view illustrating fuel nozzles **10**, air holes **12** and their peripheral portions in the entire gas turbine, taken along line C-C of FIG. **3**B. FIG. **12** illustrates a shape of the air hole **12**.

[0085] The burner plate **11** in a third embodiment is shaped such that a circular cone is hollowed out. In other words, a plane of the burner plate **11** at which an outlet portion **301** of the air hole **12** is located is shaped to open toward the combustion chamber as shown in FIG. **12**. Specifically, the plane formed by the outlet portion **301** of the air hole **12** is inclined with respect to the central axis of the burner.

[0086] An obstacle is provided on the downstream side of the outlet portion **301** of the air hole **12** so as to disturb fuel flow and air flow. This obstacle corresponds to the protrusion **1**, which is formed annular and provided for each circular row air hole. Incidentally, the protrusion **1** is located at the most downstream side of the incline outlet portion **301** of the air hole **12**.

[0087] If disturbance (secondary flow) may occur on the upstream side of a flame stabilizer used in a combustor, it is generally probable that the flames reach the upstream side of the flame stabilizer through the low flow velocity portion of the disturbance. In such a case, the flame stabilizer may be burn out. However, the plane formed at the outlet portion **301** of the air hole **12** is inclined with respect to the central axis of the burner. There is no sharply-angled portion or stagnation that causes disturbance on the upstream side of the obstacle (the protrusion). Thus, the protrusion can be prevented from being burned out to enhance the reliability of the combustor. In addition, since the protrusion **1** is provided for each circular row air hole, flame stability not only at the central portion of the burner but also at the outer circumferential portion thereof can be enhanced. In short, the flame stability of the entire burner can be enhanced.

EMBODIMENT 4

[0088] FIG. **4**B is a front view illustrating a burner plate **11** as viewed from a combustion chamber **180**. FIG. **4**A is an enlarged schematic cross-sectional view illustrating fuel nozzles **10**, air holes **12** and their peripheral portions in the entire gas turbine of FIG. **11**, taken along line D-D of FIG. **4**B.

[0089] Unlike the first embodiment, a fourth embodiment is such that a protrusion **3** is provided on the central side of a burner. In addition, the burner plate **11** is formed to have a greater thickness on the inner circumferential side of the burner (on the axial center side of the burner) than on the outer circumferential side of the burner. Changing the thickness of the burner plate **11** as described above can cause the outlet portions of the air holes **12** to differ in position from each other in the axial direction of the burner.

[0090] As shown in FIG. **4**B, the burner plate **11** is provided with such a steplike shape as that a steplike area **201** is formed on the axial center side of the burner and a recessed area **200** is formed on the outer circumferential side of the burner. The outlet portions of second and third circular row air holes **12-2**, **12-3** are arranged in the recessed area **200**. In addition, the outlet portions of the first circular row air holes **12-1** are arranged in the steplike area **201** of the burner plate **11** which has a step relative to the recessed area **200**. In the present embodiment, the steplike area **201** having the first circular row air holes **12-1** of the burner plate corresponds to the burner plate extension.

[0091] The steplike area **201** is formed in a circle relative to the axial center of the burner. Therefore, the steplike shape of the burner plate **11** is formed to continue in the circumferential direction. The lateral surface portion **202** is formed in a columnar shape.

[0092] In the present invention, a sharply-angled protrusion **3** is provided on the lateral surface portion **202** of the burner plate **11** so that the fuel flow and air flow jetted from the second circular row air holes **12-2** may collide with the lateral surface portion **202** of the burner plate **11** by use of the steplike shape of the burner plate **11**. Also the sharply-angled protrusion **3** is shaped to continue in the circumferential direction as with the steplike shape of the burner plate **11**.

[0093] This configuration forms high-temperature recirculation flow on the downstream side of the protrusion **3**. An annular space which is disposed on the downstream side of the second and third circular row air holes and defined between the liner **160** and the burner plate extension serves as a flame source forming area. The recirculation flow serves as a flame source, which applies thermal energy to unburned premixed gas jetted from the second and third circular row air holes **12** located on the outer circumferential side of the burner. Thus, the flame stability on the outer circumferential side of the burner is improved. The basic mechanism of the flame stability is the same as that of the first embodiment. In the present embodiment, the burner plate **11** has a greater thickness on the inner circumferential side of the burner (on the axial center side of the burner) than on the outer circumferential side of the burner. Therefore, it is less susceptible to areal restriction. It is possible to provide a plurality of the protrusions **3** at different positions depending on the number/positions of the air holes.

EMBODIMENT 5

[0094] FIG. **5**B is a front view illustrating a burner plate **11** as viewed from a combustion chamber **180**. FIG. **5**A is an enlarged schematic cross-sectional view illustrating fuel nozzles **10**, air holes **12** and their peripheral portions in the entire gas turbine of FIG. **11**, taken along line E-E of FIG. **5**B.

[0095] The burner plate **11** of the present embodiment has a uniform thickness and therefore the respective passage lengths of the air holes **12** are the same. A conical protrusion **4** is provided on the end face of the burner plate **11**. As shown in FIG. **5**B, the conical protrusion **4** is located at the central portion of the burner so as to disturb the fuel flow and air flow jetted from the first circular row air holes **12-1**. High-temperature recirculation flow is formed on the downstream side of the protrusion **4**. This recirculation flow applies thermal energy to unburned premixed gas to promote ignition, thereby improving flame stability.

[0096] Since the protrusion **4** of the present embodiment has a simple structure, not only a newly installed combustor but also an existing combustor additionally attached with the protrusion **4** can enhance flame stability.

[0097] In FIGS. **5**A and **5**B, the protrusion **4** is single. However, a plurality of the protrusions **4** may be installed depending on the number or arrangement of the air holes, whereby the flame stability can further be enhanced.

[0098] As shown in FIGS. **10**A and **10**B, the provision of an annular protrusion **7** between the first circular row air holes **12-1** and the second circular row air holes **12-2** can concurrently enhance the flame stability of inner and outer circumferences.

EMBODIMENT 6

[0099] In a sixth embodiment, an assembly of the fuel nozzles and air holes according to each of the structures described in the first through fifth embodiments is taken as a single burner. A plurality of the burners are combined to constitute single combustion equipment.

[0100] FIG. **6**B is a front view illustrating a burner plate **11** as viewed from a combustion chamber **180**. FIG. **6**A is an enlarged schematic cross-sectional view illustrating fuel nozzles **10**, air holes **12** and their peripheral portions in the entire gas turbine of FIG. **11**.

[0101] Referring to FIG. **6**B, one burner is arranged on the central side of the combustion equipment and six burners are arranged on the outer circumferential side thereof. A fuel system is connected to each of the burners. Every burner adopts the burner structure of FIG. **1**.

[0102] As shown in FIG. **6**A, the fuel system is divided into subsystems for each burner and the number of burners to be burned is controlled according to the load. Thus, combustion can stably be continued by varying the amount of fuel from the starting condition to 100%-load condition of the gas turbine. In addition, since each burner has a high-degree of combustion stability, the lower limit of the flow rate of fuel fed to one burner can be lowered. Combustion equipment with different capacity per one combustion chamber can be easily provided by increasing or decreasing the number of fuel nozzles.

[0103] Combustion equipment can also be configured as below. A burner embodying the present invention is disposed on the central side of the combustion equipment. Six burners each of which has a burner plate with a uniform thickness and is provided with no protrusion are arranged on the outer circumferential side of the burner disposed on the central side as above. With such arrangement, the burner disposed on the central side of the combustion equipment serves as a flame source. Thus, even in the state where the burners disposed on the outer circumferential side cannot stabilize flames by themselves, the burner disposed on the central side can apply thermal energy to the burners arranged on the outer circumferential side. Consequently, the entire combustion equipment can improve combustion stability.

[0104] The combustion equipment described in each of the first through sixth embodiments can be applied not only to a gas turbine combustor but also to various combustion equipment using gas such as methane as fuel, such as a combustor for fuel reforming mounted on a fuel cell, a combustor for a boiler, a warm air heater, an incinerator, etc.

[0105] The present configuration of the combustor can be applied to any combustor burning gaseous fuel, such as a combustor for a boiler, a combustor for fuel reforming mounted on a fuel cell, etc., as well as to a combustor for a gas turbine.

What is claimed is:

1. Combustion equipment comprising:

a burner plate in which fuel and air are mixed with each other while the fuel and air pass through an air hole;

a burner plate extension which is a portion of the burner plate and extends toward a combustion chamber side spaced apart from the air hole; and

a protrusion disposed on the combustion chamber side of the burner plate extension so as to protrude in direction perpendicular to a direction where a flow of the fuel passes;

wherein a gap between opposite portions of the protrusion is greater than a diameter of the air hole; and

wherein a flame source forming area is defined between the burner plate, the burner plate extension and the protrusion.

2. Combustion equipment comprising:

a steplike-shaped burner plate in which fuel and air are mixed with each other while the fuel and air pass through an air hole;

a burner plate extension which is an external circumferential portion of the burner plate and extends toward a combustion chamber side spaced apart from the air hole; and

a sharply-angled protrusion disposed on the combustion chamber side of the burner plate extension so as to protrude in a direction perpendicular to a direction where a flow of the fuel passes;

wherein a gap between opposite portions of the protrusion is greater than a diameter of the air hole; and

wherein a flame source forming area is defined between the burner plate, the burner plate extension and the protrusion.

3. The combustion equipment according to claim **1**,

wherein the burner plate extension is formed steplike such that the burner plate is thicker in thickness on an axial center side of the burner than on an outer circumferential side thereof; and

wherein the protrusion is provided on the external circumferential side of the steplike shape.

4. The combustion equipment according to claim **1**,

wherein the burner plate has a uniform thickness; and

wherein the protrusion of the burner plate which disturbs the fuel flow and air flow jetted from the air hole disposed on the axial center side of the burner is located on the downstream side of a jetting-out portion of the air hole.

5. The combustion equipment according to claim **1**,

wherein the air hole is inclined with respect to an axial center of the burner.

6. The combustion equipment according to claim **1**,

wherein the protrusion is a square protrusion.

7. The combustion equipment according to claim **1**,

wherein the combustion equipment is provided with a plurality of the burners each provided with the burner plate.

8. The combustion equipment according to claim **6**,

wherein the burner having the steplike-shaped burner plate is disposed at the axial center of the combustion equipment, and a burner having the burner plate with a uniform thickness is disposed on the outer circumferential side of the combustion equipment.

9. A burner combustion method comprising;

a first step in which coaxial jet flow is formed inside an air hole provided in a burner plate, the coaxial jet flow being such that air flow is formed on the outer circumferential side of fuel flow;

a second step in which the coaxial jet flow is jetted from the air hole to a combustion chamber; and

a third step in which the coaxial jet flow collides against a protrusion of a burner plate extension which extends toward the combustion chamber side spaced apart from the air hole, thereby forming a flame source.

10. The burner combustion method according to claim **9**, wherein the fuel flow and air flow jetted from the air hole has a velocity component swirling around a central axis of the burner.

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