



(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
13.09.2017 Bulletin 2017/37

(51) Int Cl.:
F02M 69/54 ^(2006.01) **F02B 25/04** ^(2006.01)
F02M 21/02 ^(2006.01) **F02M 69/10** ^(2006.01)
F02M 69/52 ^(2006.01)

(21) Application number: **15856740.4**

(22) Date of filing: **02.11.2015**

(86) International application number:
PCT/JP2015/080894

(87) International publication number:
WO 2016/072375 (12.05.2016 Gazette 2016/19)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **04.11.2014 JP 2014224455**
04.11.2014 JP 2014224456

(71) Applicant: **IHI Corporation**
Tokyo 135-8710 (JP)

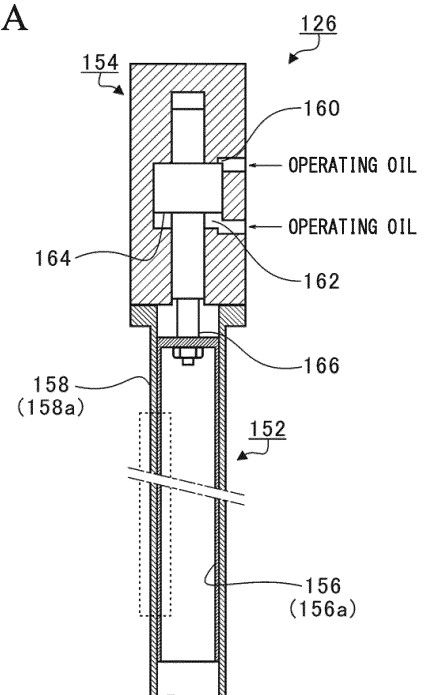
(72) Inventors:
• **YAMADA, Takeshi**
Tokyo 135-8710 (JP)
• **UMEMOTO, Yoshiyuki**
Aioi-shi
Hyogo 678-0041 (JP)
• **TERAMOTO, Jun**
Aioi-shi
Hyogo 678-0041 (JP)
• **HIROSE, Takayuki**
Aioi-shi
Hyogo 678-0041 (JP)

(74) Representative: **TBK**
Bavariaring 4-6
80336 München (DE)

(54) **UNIFLOW SCAVENGING TWO-CYCLE ENGINE**

(57) A uniflow scavenging two-cycle engine includes: a cylinder in which a combustion chamber is formed; a piston that slides in the cylinder; a scavenging port that is provided one end side of the piston in a stroke direction in the cylinder and suctions active gas in the combustion chamber in response to a sliding motion of the piston; and a fuel injecting unit (126) that is provided on an outer side of the cylinder in a radial direction from the scavenging port and injects fuel gas into the active gas which is suctioned into the scavenging port. The fuel injecting unit includes an inner pipe (156) which has an inner hole penetrating between an inside and an outside thereof and through which fuel gas is guided to the inside, an outer pipe (158) which has an outer hole penetrating between an inside and an outside thereof and stows the inner pipe in the inside thereof so as to form a double pipe with the inner pipe, and a driving unit (154) which changes relative positions of the inner pipe and the outer pipe and changes an opening amount as an area of an overlap between the inner hole and the outer hole.

FIG. 5A



Description

Technical Field

[0001] The present disclosure relates to a uniflow scavenging two-cycle engine that suctions fuel gas along with active gas from a scavenging port into a cylinder.

[0002] Priority is claimed on Japanese Patent Application No. 2014-224455 and Japanese Patent Application No. 2014-224456, filed on November 4, 2014, the content of which is incorporated herein by reference.

Background Art

[0003] A uniflow scavenging two-cycle engine that is also used as an engine in a ship is provided with a scavenging port on one end side and an exhaust port on the other end side of a piston in a stroke direction in a cylinder. When active gas is suctioned from the scavenging port to a combustion chamber in an intake (feeding) stroke, exhaust gas produced in combustion behavior is pushed and is exhausted from the exhaust port with the suctioned active gas.

[0004] In such a uniflow scavenging two-cycle engine, technology of supplying fuel gas from the scavenging port side into the cylinder without directly injecting, into the combustion chamber, the fuel gas, which is a gaseous fuel, as a fuel is developed. For example, in an engine disclosed in Patent Document 1, an annular chamber that extends in a circumferential direction of a cylinder is formed on an upper side of a scavenging port in an outer wall of the cylinder. In addition, a nozzle pipe penetrates an inner wall of the scavenging port from the chamber and extends to the inside of the scavenging port. When a control valve that communicates with the chamber is opened, fuel gas is supplied into the chamber through the control valve and the fuel gas is injected into the scavenging port through the nozzle pipe from the chamber.

Citation List

Patent Document

[0005] [Patent Document 1] Japanese Patent (Granted) Application No. 3908855

Summary of Invention

Technical Problem

[0006] In a configuration disclosed in Patent Document 1, the control valve is closed, and thereby injection of the fuel gas is stopped. However, the fuel gas remaining in the chamber or the nozzle pipe is likely to be injected through the scavenging port after the control valve is closed. In other words, there is an occurrence of delay from the time when the control valve is closed to the time when the injection of the fuel gas is actually and com-

pletely stopped.

[0007] In consideration of such a problem, an object of the present disclosure is to provide a uniflow scavenging two-cycle engine that is capable of rapidly stopping injection of fuel gas.

Solution to Problem

[0008] A first aspect of a uniflow scavenging two-cycle engine of the present disclosure includes a cylinder in which a combustion chamber is formed; a piston that slides in the cylinder; a scavenging port that is provided one end side of the piston in a stroke direction in the cylinder and suctions active gas in the combustion chamber in response to a sliding motion of the piston; and a fuel injecting unit that is provided on an outer side of the cylinder in a radial direction from the scavenging port and injects fuel gas into the active gas which is suctioned into the scavenging port. Furthermore, the fuel injecting unit includes an inner pipe which has an inner hole penetrating between an inside and an outside thereof and through which fuel gas is guided to the inside, an outer pipe which has an outer hole penetrating between an inside and an outside thereof and stows the inner pipe in the inside thereof so as to form a double pipe with the inner pipe, and a driving unit which changes relative positions of the inner pipe and the outer pipe and changes an opening amount as an area of an overlap between the inner hole and the outer hole.

Advantageous Effects of Invention

[0009] According to the uniflow scavenging two-cycle engine of the present disclosure, it is possible to rapidly stop the injection of the fuel gas.

Brief Description of Drawings

[0010]

FIG. 1 is a view showing an entire configuration of a uniflow scavenging two-cycle engine.

FIG. 2 is a view showing a configuration in the vicinity of a scavenging port in FIG. 1.

FIG. 3 is a view showing a gas injecting valve.

FIG. 4 is a sectional view taken along line IV-IV in FIG. 2.

FIG. 5A is a view showing a fuel injecting unit.

FIG. 5B is a view showing the fuel injecting unit.

FIG. 6A is a sectional view of an inner pipe and an outer pipe.

FIG. 6B is a sectional view of the inner pipe and the outer pipe.

FIG. 7 is a first view showing a positional relationship between inner holes and outer holes.

FIG. 8 is a second view showing the positional relationship between the inner holes and the outer holes.

FIG. 9A is a view showing a change in relative posi-

tions of the inner holes and the outer holes stage by stage.

FIG. 9B is a view showing the change in the relative positions of the inner holes and the outer holes stage by stage.

FIG. 9C is a view showing the change in the relative positions of the inner holes and the outer holes stage by stage.

FIG. 9D is a view showing the change in the relative positions of the inner holes and the outer holes stage by stage.

FIG. 10A is a diagram showing a relationship between a concentration of mixture and a degree of opening of the scavenging port according to the present disclosure.

FIG. 10B is a diagram showing a relationship between a concentration of mixture and a degree of opening of the scavenging port according to a comparative example.

FIG. 11A is a view showing inner holes and outer holes according to a first modification example.

FIG. 11B is a view showing the inner holes and the outer holes according to the first modification example.

FIG. 12A is a view showing inner holes and outer holes according to a second modification example.

FIG. 12B is a view showing the inner holes and the outer holes according to the second modification example.

FIG. 13A is a view showing inner holes and outer holes according to a third modification example.

FIG. 13B is a view showing the inner holes and the outer holes according to the third modification example.

FIG. 14A is a view showing a fuel injecting unit according to a fourth modification example.

FIG. 14B is a view showing inner holes and outer holes according to the fourth modification example.

FIG. 15A is a view showing a fuel injecting unit according to a fifth modification example.

FIG. 15B is a view showing inner holes and outer holes according to the fifth modification example.

FIG. 16A is a view showing a fuel injecting unit according to a sixth modification example.

FIG. 16B is a view showing inner holes and outer holes according to the sixth modification example.

FIG. 17 is a view showing another entire configuration of a uniflow scavenging two-cycle engine.

FIG. 18 is a sectional view taken along line II-II in FIG. 17.

Fig. 19 is an enlarged view of a portion in a dashed line in FIG. 17.

FIG. 20 is a view showing a fuel pipe and an opening-closing mechanism in FIG. 19.

FIG. 21A is a view showing opening and closing of a fuel injection opening.

FIG. 21B is a view showing opening and closing of the fuel injection opening.

FIG. 21C is a view showing opening and closing of the fuel injection opening.

FIG. 22A is a diagram showing a relationship between a concentration of mixture and a degree of opening of the scavenging port according to the present disclosure.

FIG. 22B is a diagram showing a relationship between a concentration of mixture and a degree of opening of the scavenging port according to a comparative example.

Description of Embodiments

[0011] Hereinafter, a preferred embodiment according to the present disclosure will be described with reference to the accompanying figures. The dimensions, the materials, the specific numbers other than the dimensions and the materials, or the like is provided only as an example for easy understanding of the disclosure, and the disclosure is not limited thereto except for a case where particular description is provided. Note that, in the present specification and the figures, an element having substantially the same function and configuration is assigned with the same reference sign and a repeated description thereof is omitted, and illustration of an element without a direct relationship with the present disclosure is omitted in the figures.

[0012] FIG. 1 is a view showing an entire configuration of a uniflow scavenging two-cycle engine 100. The uniflow scavenging two-cycle engine 100 of the embodiment is used in a ship or the like. Specifically, the uniflow scavenging two-cycle engine 100 is configured to include a cylinder 110, a piston 112, an exhaust port 114, an exhaust valve 116, a scavenging port 118, a scavenging chamber 120, a gas supply pipe 122, a gas injecting valve 124, and a fuel injecting unit 126.

[0013] In the uniflow scavenging two-cycle engine 100, exhaust, intake, compression, and combustion are performed during two strokes of an ascending stroke and a descending stroke of the piston 112 and the piston 112 slides in the cylinder 110. One end of a piston rod 112a is fixed to the piston 112. In addition, a crosshead (not shown) is connected to the other end of the piston rod 112a, and the crosshead reciprocates along with the piston 112. When the crosshead reciprocates in response to the reciprocating of the piston 112, a crankshaft (not shown) rotates by interlocking with the reciprocating of the crosshead.

[0014] The exhaust port 114 is an opening provided in a cylinder head 110a positioned above top dead center of the piston 112, and is opened and closed to discharge exhaust gas produced after combustion in the combustion chamber 128. The exhaust valve 116 slides vertically at a predetermined timing by an exhaust valve driving device 116a and opens and closes the exhaust port 114. When the exhaust port 114 is opened, exhaust gas is discharged from the cylinder 110 via the exhaust port 114.

[0015] The scavenging port 118 is a hole penetrating from an inner circumferential surface (inner circumferential surface of a cylinder liner 110b) to an outer circumferential surface of the cylinder 110 on the lower end side, and a plurality of scavenging ports are provided all around the circumference of the cylinder 110. The scavenging ports 118 suction active gas in the cylinder 110 in response to a sliding motion of the piston 112. The active gas contains an oxidizing agent such as oxygen or ozone, or a mixture thereof (for example, air).

[0016] FIG. 2 is a view showing the vicinity of the scavenging port 118 in FIG. 1. As shown in FIG. 2, the scavenging port 118 is provided in a region positioned in the scavenging chamber 120 in the cylinder 110. Active gas (for example, air) compressed by a blower (not shown) is guided into the scavenging chamber 120.

[0017] Therefore, when the scavenging port 118 is opened in response to the sliding motion of the piston 112, the active gas is suctioned from the scavenging chamber 120 through the scavenging port 118 into the cylinder 110 due to differential pressure between the scavenging chamber 120 and the cylinder 110. The active gas suctioned in the cylinder 110 is guided by the piston 112 to the combustion chamber 128.

[0018] The gas supply pipe 122, through which a fuel tank (not shown), in which fuel gas is stored, and the gas injecting valve 124, guides the fuel gas from the fuel tank to the gas injecting valve 124.

[0019] FIG. 3 is a view showing the gas injecting valve 124. As shown in FIG. 3, a hydraulic piston 130 is disposed inside a main body 124a of the gas injecting valve 124, and the hydraulic piston 130 functions as a partition between a hydraulic chamber 132 and a spring chamber 134 which are formed inside the main body 124a. The hydraulic piston 130 is able to slide on the hydraulic chamber 132 side and on the spring chamber 134 side inside the main body 124a.

[0020] The hydraulic chamber 132 communicates with an operating oil pipe 136 and is filled with operating oil supplied from the operating oil pipe 136. The hydraulic piston 130 is pressed upward in FIG. 3 by the operating oil in the hydraulic chamber 132.

[0021] In addition, a spring member 138 is disposed in the spring chamber 134, and the spring member 138 abuts on the hydraulic piston 130 on the spring chamber 134 side. A bias force of the spring member 138 is applied to the hydraulic piston 130 in an orientation against a pressing force produced by the operating oil.

[0022] Hence, when the operating oil supplied to the hydraulic chamber 132 has high hydraulic pressure, the hydraulic piston 130 pressed with the operating oil moves upward in the main body 124a in FIG. 3. When the operating oil has a low hydraulic pressure, the hydraulic piston 130 moves downward in the main body 124a in FIG. 3 due to the bias force of the spring member 138.

[0023] In addition, an operating oil leak pipe 140 communicates to the hydraulic piston 130, operating oil, which leaks from the hydraulic chamber 132 due to the

movement of the hydraulic piston 130, is discharged to the outside of the main body 124a through the operating oil leak pipe 140.

[0024] Further, a gas chamber 142 connected to a communication passage 122a communicating with the gas supply pipe 122 is provided above the spring chamber 134 inside the main body 124a in FIG. 3, and thus fuel gas is supplied from the gas supply pipe 122.

[0025] Communication piping 148 communicating with the fuel injecting unit 126 is connected to one end side of the main body 124a of the gas injecting valve 124, and the gas chamber 142 communicates with the communication piping 148 via a communication opening 124b formed in one end of the main body 124a.

[0026] A valve body 146 is formed in one end of a shaft 144, and the valve body 146 is positioned on the outer side of the communication opening 124b. In addition, the other end side of the shaft 144 is fixed to the hydraulic piston 130, and the shaft penetrates through the main body 124a from the gas chamber 142 to the spring chamber 134. A gas leak pipe 150 communicates with the spring chamber 134, and the fuel gas, which leaks from the gas chamber 142 to the spring chamber 134, is discharged to the outside of the main body 124a through the gas leak pipe 150.

[0027] As described above, when the hydraulic piston 130 moves due to the hydraulic pressure, the valve body 146 opens or closes the communication opening 124b. The gas injecting valve 124 actuates the valve body 146 with the hydraulic pressure, and supply of the fuel gas from the gas supply pipe 122 to the communication piping 148 is started or stopped.

[0028] In addition, as shown in FIG. 2, the fuel injecting unit 126 is provided with fuel pipe 152 and a driving unit 154. The fuel pipe 152 communicates with the communication piping 148, and the fuel gas supplied from the communication piping 148 flows into the fuel pipe. The driving unit 154 controls injection of the fuel gas from the fuel pipe 152 by opening or closing of the fuel pipe 152.

[0029] FIG. 4 is a sectional view taken along line IV-IV in FIG. 2. In FIG. 4, for easy understanding, a cross-sectional plane of the fuel pipe 152 is shown in a simplified manner, and an internal configuration of the fuel pipe 152 will be described below in detail. As shown in FIG. 4, the fuel pipe 152 is provided on an outer side of the cylinder 110 in a radial direction from the scavenging port 118 and injects fuel gas into the active gas which is suctioned into the scavenging port 118.

[0030] In an example shown in FIG. 4, the fuel pipe 152 is disposed on the outer side of the outer surface of the cylinder 110 in the radial direction between adjacent scavenging ports 118, and thus the fuel pipe 152 is unlikely to interfere with flowing of the active gas.

[0031] In the example shown in FIG. 4, a case, where the same number of the fuel pipes 152 and the scavenging ports 118 is disposed, is described; however, the number of the fuel pipes 152 and the scavenging ports 118 may be different from each other, and, for example,

two scavenging ports 118 may be provided for each of the fuel pipes 152.

[0032] FIGS. 5A and 5B are views showing the fuel injecting unit 126. As shown in FIGS. 5A and 5B, the fuel pipe 152 is configured to have an inner pipe 156 and an outer pipe 158. The fuel gas is guided into the inside of the inner pipe 156, and the outer pipe 158 stows the inner pipe 156 inside thereof and forms a double pipe with the inner pipe 156.

[0033] An outer diameter of the inner pipe 156 is slightly smaller than an inner diameter of the outer pipe 158, and the outer circumferential surface of the inner pipe 156 substantially entirely abuts on the inner circumferential surface of the outer pipe 158. In addition, a front end of the inner pipe 156 on the lower side in FIGS. 5A and 5B has an opening, and the inside of a main body 158a of the outer pipe 158 and the inside of a main body 156a of the inner pipe 156 communicate with each other via the opening.

[0034] The outer pipe 158 communicates with the communication piping 148 shown in FIG. 3, and the fuel gas is supplied to the outer pipe 158 from the communication piping 148. The fuel gas guided to the inside of the main body 158a of the outer pipe 158 flows into the inside of the main body 156a of the inner pipe 156 from the front end (lower end) of the inner pipe 156.

[0035] The driving unit 154 includes two hydraulic chambers 160 and 162, and a hydraulic piston 164 functioning as a partition between the two hydraulic chambers 160 and 162. In addition, a shaft 166 is fixed to the hydraulic piston 164, and a base end (upper end) of the inner pipe 156 is fixed to a front end side of the shaft 166 on the lower side in FIGS. 5A and 5B.

[0036] From the state shown in FIG. 5A, when the operating oil supplied to the hydraulic chamber 160 has the high hydraulic pressure, the shaft 166 moves downward in FIGS. 5A and 5B, and the inner pipe 156 moves downward, in FIGS. 5A and 5B, in response to the movement, as shown in FIG. 5B.

[0037] Conversely, from the state shown in FIG. 5B, when the operating oil supplied to the hydraulic chamber 162 has the high hydraulic pressure, the shaft 166 moves upward in FIGS. 5A and 5B, and the inner pipe 156 moves upward, in FIGS. 5A and 5B, in response to the movement, as shown in FIG. 5A. In this manner, the driving unit 154 causes the inner pipe 156 to move in a vertical direction (that is, a stroke direction of the piston 112 in the cylinder 110, hereinafter, abbreviated to a stroke direction in some cases) in FIGS. 5A and 5B, and changes relative positions of the inner pipe 156 and the outer pipe 158.

[0038] FIGS. 6A and 6B are sectional views of the inner pipe 156 and the outer pipe 158, and showing portions surrounded by dashed lines in FIGS. 5A and 5B which are rotated by 90 degrees in the counterclockwise direction. In other words, in FIGS. 6A and 6B, the right side is the bottom dead center side (one end side in the stroke direction) of the piston 112, and the left side is the top

dead center side (the other end side in the stroke direction) of the piston 112. As shown in FIGS. 6A and 6B, the inner pipe 156 has inner holes 174 penetrating through the main body 156a of the inner pipe 156 from the inside to the outside thereof, and the outer pipe 158 has outer holes 176 penetrating through the main body 158a of the outer pipe 158 from the inside to the outside thereof. A plurality of inner holes 174 and outer holes 176 are formed to be separated from one another in the stroke direction (rightward-leftward direction in FIGS. 6A and 6B).

[0039] As shown in FIG. 6A, when the inner hole 174 and the outer hole 176 overlap each other, the fuel gas flowing inside the inner pipe 156 is injected from the fuel pipe 152 through the inner hole 174 and the outer hole 176, and is joined to the active gas suctioned into the scavenging port 118.

[0040] When the inner pipe 156 moves to the right side (top dead center side of the piston 112), in FIGS. 6A and 6B, in the stroke direction, all of the inner holes 174 and the outer holes 176 do not overlap each other as shown in FIG. 6B, and the injection of the fuel gas from the fuel pipe 152 is stopped. As described above, the driving unit 154 changes an opening amount as an area of the overlap between the inner holes 174 and the outer holes 176. As a result, since an opening of the fuel pipe 152, which injects the fuel gas, is opened or closed, it is possible to rapidly stop the injection of the fuel gas without a delay.

[0041] FIG. 7 is a first view showing a positional relationship between the inner holes 174 and the outer holes 176, and shows the external appearance in which the same positions in FIGS. 6A and 6B are disposed in the same orientation as in FIGS. 6A and 6B. In other words, in FIG. 7, the right side is the bottom dead center side (one end side in the stroke direction) of the piston 112, and the left side is the top dead center side (the other end side in the stroke direction) of the piston 112. In FIG. 7, a dashed line represents a line showing an outer edge of the inner pipe 156 stowed in the outer pipe 158.

[0042] As shown in FIG. 7, the plurality of outer holes 176 have a circular shape in the cross-sectional plane of which normal axis is perpendicular to a penetrating direction of the outer pipe 158 and have the same diameter, and the plurality of inner holes 174 have different lengths from each other in the stroke direction. Specifically, the inner holes 174 formed on the top dead center side (left side in FIG. 7) of the piston 112 are longer in length in the stroke direction than the inner holes 174 formed on the bottom dead center side (right side in FIG. 7) of the piston 112. The inner hole 174 on the rightmost side (n-th hole from the left in FIG. 7) has the same shape as the outer hole 176 in the cross-sectional plane of which normal axis is perpendicular to the penetrating direction of the inner pipe 156.

[0043] In FIG. 7, both ends of each first to (n-1)-th inner holes 174 from the left have a semicircular arc shape with the same diameter as that of the outer holes 176, and a straight line shape is formed between two semicir-

cular arcs. The lengths of the portions of the straight line shapes in the stroke direction are different for each of the inner holes 174.

[0044] A distance P between adjacent outer holes 176 is constant. In addition, a distance A from the center of the left semicircular arc, in FIG. 7, of the inner hole 174 to the center of the corresponding outer hole 176 is constant, also for any inner hole 174 and the corresponding outer hole 176.

[0045] Further, as shown in FIG. 7, when the inner hole 174 is positioned on the left side from the corresponding outer hole 176 and the holes do not overlap each other, B represents a distance from the center of the right semicircular arc, in FIG. 7, of the inner hole 174 to the center of the outer hole 176. Numbers are assigned to reference signs ($B_1, B_2, B_3, \dots, B_{n-1}, B_n$) representing the distances B in order from the left in FIG. 7. At this time, a relationship of $B_1 < B_2 < B_3 < \dots < B_{n-1} < B_n$ is obtained.

[0046] FIG. 8 is a second view showing the positional relationship between the inner holes 174 and the outer holes 176. In FIG. 8, for easy understanding, reference signs assigned to the inner holes 174 and the outer holes 176 are omitted, the inner holes 174 are represented by hatched portions and the outer holes 176 are represented by cross-hatched portions. In addition, in FIG. 8, the right side is the bottom dead center side (one end side in the stroke direction) of the piston 112, and the left side is the top dead center side (the other end side in the stroke direction) of the piston 112. In addition, d represents the inner diameter of the outer hole 176, L represents the length of the inner hole 174, and numbers are assigned to reference signs in order from the left in FIG. 8.

[0047] The inner hole 174 has a length L shorter, by the inner diameter d of the outer hole 176, than an adjacent inner hole 174 on the left side in FIG. 8. At this time, the distance P of the outer holes 176 is longer than a product of the inner diameter d and (n+1) obtained by adding 1 to the number n of the outer holes 176.

[0048] When the inner hole 174 moves to the top dead center side (left side in FIG. 8) of the piston 112, by the inner diameter d of the outer hole 176, from a state of a position A at which all of the inner holes 174 and the outer holes 176 completely overlap, to a state of a position B, the n-th (on the right side, first) inner hole 174 from the left and the outer hole 176 do not overlap each other.

[0049] Further, when the inner pipe 156 moves by the inner diameter d to a position C and then a position D, from the inner hole 174 on the right side in FIG. 8, the overlap with the outer hole 176 is sequentially cancelled. Finally, in a state of a position X, none of the inner holes 174 and the outer holes 176 overlap each other.

[0050] FIGS. 9A to 9D are views showing a change in the relative positions of the inner pipe 156 and the outer pipe 158 stage by stage. In FIGS. 9A to 9D, the right side is the bottom dead center side (one end side in the stroke direction) of the piston 112, and the left side is the top dead center side (the other end side in the stroke direction) of the piston 112. As shown in FIG. 9A, when the

inner pipe 156 moves to the bottom dead center side (right side in FIGS. 9A to 9D) of the piston 112 from the state in which all of the inner holes 174 and the outer holes 176 do not overlap each other, the first inner hole 174 from the top dead center side (left side in FIGS. 9A to 9D) of the piston 112 starts to overlap the outer hole 176, as shown in FIG. 9B.

[0051] Further, when the inner pipe 156 moves to the bottom dead center of the piston 112, the first and second inner holes 174 from the top dead center side (left side in FIGS. 9A to 9D) of the piston 112 overlaps the outer hole 176 so as to achieve a fully open state, and the third inner hole 174 starts to overlap the outer hole 176 as shown in FIG. 9C.

[0052] When the movement of the inner pipe 156 progresses, finally, as shown in FIG. 9D, all of the inner holes 174 overlap the outer holes 176 so as to achieve a fully open state. Then, the inner pipe 156 returns to move toward the top dead center side of the piston 112, and transition from the state in FIG. 9D to the state in FIG. 9A is performed stage by stage.

[0053] In this manner, the inner holes 174 and the outer holes 176 are sequentially opened from the top dead center side (left side in FIGS. 9A to 9D) of the piston 112, and all of the inner holes 174 and the outer holes 176 overlap each other so as to achieve the fully open state. Then, the holes are sequentially closed from the bottom dead center side (right side in FIGS. 9A to 9D) of the piston 112.

[0054] Here, an opening region, which is positioned relatively on one end side (right side in FIGS. 9A to 9D) in the stroke direction, of a portion in which the inner pipe 156 and the outer pipe 158 overlap each other, and is formed by the overlap between the inner holes 174 and the outer holes 176, is referred to as a small-flow-quantity opening region Os.

[0055] In addition, an opening region, which is positioned on the top dead center side (left side in FIGS. 9A to 9D) of the piston 112 from the small-flow-quantity opening region Os, of a portion in which the inner pipe 156 and the outer pipe 158 overlap each other, is referred to as a large-flow-quantity opening region Ob. Here, the small-flow-quantity opening region Os and the large-flow-quantity opening region Ob are regions having a predetermined size including the outer hole 176 in the outer pipe 158.

[0056] In addition, the inner hole 174 and the outer hole 176 which form the large-flow-quantity opening region Ob are separated in the stroke direction from the inner hole 174 and the outer hole 176 which form the small-flow-quantity opening region Os.

[0057] At this time, the inner hole 174 and the outer hole 176 which form the large-flow-quantity opening region Ob are positioned on the top dead center side (left side in FIGS. 9A to 9D) of the piston 112 from the inner hole 174 and the outer hole 176 which form the small-flow-quantity opening region Os. Therefore, the large-flow-quantity opening region Ob is in a state in which the

inner hole 174 and the outer hole 176 overlap each other for a longer time than the small-flow-quantity opening region Os. In addition, in the large-flow-quantity opening region Ob, the inner hole 174 and the outer hole 176 overlap each other earlier than in the small-flow-quantity opening region Os, and the overlap between the inner hole 174 and the outer hole 176 is delayed before being cancelled.

[0058] FIGS. 10A and 10B are diagrams showing a relationship between a degree of opening of the scavenging port 118 and a concentration of mixture. In FIGS. 10A and 10B, the vertical direction represents the stroke direction of the piston 112, the upper side corresponds to the top dead center side (the other end side in the stroke direction) of the piston 112, and the lower side corresponds to the bottom dead center side (the one end side in the stroke direction) of the piston 112.

[0059] The scavenging port 118 has an opening area which changes depending on the position of the piston 112 as shown in the graph of the opening area of the port in FIGS. 10A and 10B. When the scavenging port 118 starts to be opened, the scavenging port 118 starts to be opened from a portion thereof on the top dead center side of the piston 112, finally, to a portion thereof on the bottom dead center side. When the scavenging port 118 starts to be closed, the scavenging port 118 starts to be closed from the portion thereof on the bottom dead center side of the piston 112, finally, to the portion thereof on the top dead center side.

[0060] As a result, a scavenging air amount (scavenging active gas amount) changes in proportion to an opening area of the port, as shown in the graph of the scavenging air amount in FIGS. 10A and 10B. At this time, in a comparative example shown in FIG. 10B, an injection amount of the fuel gas is not proportional to the opening area of the port, as shown in the graph of the gas injection amount. Therefore, as shown in the graph of the concentration of mixture in FIG. 10B, the concentration of mixture of the fuel gas and the active gas from the scavenging port 118 is likely to be locally rich.

[0061] In the embodiment, as shown in FIG. 10A, the inner pipe 156 shifts in proportion to the opening area of the port. As a result, the inner holes 174 and the outer holes 176 are sequentially opened from the top dead center side of the piston 112 while the opening area of the scavenging port 118 increases as described above. When the opening area of the scavenging port 118 decreases, the inner holes 174 and the outer holes 176 are sequentially closed from the bottom dead center side of the piston 112.

[0062] Therefore, the injection amount of the fuel gas increases and decreases in proportional to an amount of the active gas, as shown in the graph of the gas injection amount in FIG. 10A. Therefore, it is possible to maintain substantially a constant concentration of mixture of the fuel gas and the active gas flowing through the scavenging port 118.

[0063] In addition, the large-flow-quantity opening re-

gion Ob positioned on the top dead center side is in the state in which the inner hole 174 and the outer hole 176 overlap each other for a longer time than the small-flow-quantity opening region Os positioned on the bottom dead center side. Therefore, the injection amount of the fuel gas is large from the large-flow-quantity opening region Ob on the top dead center side in which the opening time is long, of the scavenging port 118, and an even concentration of the mixture is obtained.

[0064] In addition, as described above, in the large-flow-quantity opening region Ob, the inner hole 174 and the outer hole 176 overlap each other earlier than in the small-flow-quantity opening region Os, and the overlap between the inner hole 174 and the outer hole 176 is delayed before being cancelled. Therefore, it is possible to inject the fuel gas by opening and closing the inner holes 174 and the outer holes 176 in the large-flow-quantity opening region Ob and the small-flow-quantity opening region Os at timings closer to the opening and closing of the scavenging port 118.

[0065] FIGS. 11A and 11B are views showing inner holes 274 and outer holes 276 according to a first modification example. As shown in FIGS. 11A and 11B, in the first modification example, the inner hole 274 and the outer hole 276, which have a correspondence relationship, have the same shape in the cross-sectional plane of which normal axis is perpendicular to the penetrating direction of the inner pipe 156 and the outer pipe 158, and each has a rectangular shape. The lengths of the inner holes 274 and the outer holes 276 in the vertical direction in FIGS. 11A and 11B (length in a direction perpendicular to the stroke direction) are longer on the top dead center side than on the bottom dead center side, and the lengths of the inner holes 274 and the outer holes 276 in the rightward-leftward direction in FIGS. 11A and 11B (length in the stroke direction) are the same.

[0066] When the inner holes 274 and the outer holes 276 overlap each other as shown in FIG. 11B, from a state in which all of the inner holes 274 and the outer holes 276 are closed as shown in FIG. 11A, the opening amount increases on the top dead center side.

[0067] In other words, the large-flow-quantity opening region Ob has the larger opening amount all the times than the small-flow-quantity opening region Os from start to end of the overlap between the inner holes 274 and the outer holes 276. Therefore, of the scavenging port 118, the amount of the fuel gas, which is injected on the top dead center side on which a relatively large quantity of the active gas flows, increases, and the amount of the fuel gas, which is injected on the bottom dead center side on which a relatively small quantity of the active gas flows, decreases. Thus, it is possible to obtain the even concentration of the mixture.

[0068] FIGS. 12A and 12B are views showing inner holes 374 and outer holes 376 according to a second modification example. As shown in FIGS. 12A and 12B, in the second modification example, four circular inner holes 374 are provided with respect to one circular outer

hole 376. In addition, of a plurality of outer holes 376, the outer hole on the top dead center side has the largest diameter, and the diameters of the outer holes gradually decrease as the outer holes are close to the bottom dead center side.

[0069] In a state shown in FIG. 12A, the inner holes 374 have diameters which gradually increases from that of the inner hole closer to the corresponding outer hole 376.

[0070] As shown in FIG. 12B, when the inner pipe 156 moves to the bottom dead center side, one of the four inner holes 374 overlaps the outer hole 376. Further, when the inner pipe 156 moves to the bottom dead center side, the overlap between the inner hole 374 and the outer hole 376 is cancelled temporarily, and then the next inner hole 374 and the outer hole 376 overlap each other. In this manner, the plurality of inner holes 374 sequentially overlap the one outer hole 376 and the fuel gas is injected.

[0071] At this time, an inner diameter of the outer hole 376 is larger on the top dead center side, and inner diameters of the inner holes 374 that overlap the outer hole 376 sequentially increase as the holes are close to the top dead center. Therefore, as the inner pipe 156 moves to the bottom dead center side, the large-flow-quantity opening region Ob on the top dead center side has the opening area larger than that of the small-flow-quantity opening region Os stage by stage. As the inner pipe 156 returns to move to the top dead center side, the opening area on the top dead center side decreases stage by stage.

[0072] FIGS. 13A and 13B are views showing an inner hole 474 and an outer hole 476 according to a third modification example. As shown in FIGS. 13A and 13B, in the third modification example, one inner hole 474 and one outer hole 476 are formed.

[0073] The outer hole 476 has a width (width in a direction perpendicular to the stroke direction) in the vertical direction in FIGS. 13A and 13B, which gradually decreases from the top dead center side to the bottom dead center side. On the other hand, the inner hole 474 has a width in the vertical direction in FIGS. 13A and 13B, which is substantially constant from the top dead center side toward the bottom dead center side.

[0074] When the inner pipe 156 moves to the bottom dead center side as shown in FIG. 13B, from a state in which the inner hole 474 and the outer hole 476 do not overlap each other as shown in FIG. 13A, the inner hole 474 and the outer hole 476 gradually overlap each other.

[0075] At this time, by a difference in width of the outer hole 476 in the vertical direction in FIGS. 13A and 13B, the large-flow-quantity opening region Ob has the larger opening amount than the small-flow-quantity opening region Os. In addition, similar to the embodiment described above, the large-flow-quantity opening region Ob is in the state in which the inner hole 474 and the outer hole 476 overlap each other for a longer time than the small-flow-quantity opening region Os, and thus the even con-

centration of the mixture is obtained.

[0076] Further, in the large-flow-quantity opening region Ob, the inner hole 474 and the outer hole 476 overlap each other earlier than in the small-flow-quantity opening region Os, and the overlap between the inner hole 474 and the outer hole 476 is delayed before being cancelled. Therefore, it is possible to open and close the inner hole 474 and the outer hole 476 in the large-flow-quantity opening region Ob and the small-flow-quantity opening region Os at timings closer to the opening and closing of the scavenging port 118.

[0077] FIGS. 14A and 14B are views showing a fuel injecting unit 526 according to a fourth modification example. The fuel injecting unit 126 of the embodiment described above stops the injection of the fuel gas by cancelling the overlap between the inner holes 174 of the inner pipe 156 and the outer holes 176 of the outer pipe 158. On the other hand, in the fourth modification example, as shown in FIG. 14A, the injection of the fuel gas is stopped with a valve body 572, in addition to the cancel of the overlap between the inner holes 174 of the inner pipe 156 and the outer holes 176 of the outer pipe 158.

[0078] Specifically, the fuel injecting unit 526 is provided with a gas chamber 568, which communicates with the communication piping 148 shown in FIG. 3, between the hydraulic chamber 162 and the inner pipe 156, and the fuel gas is supplied from the communication piping 148. The gas chamber 568 communicates with the inside of the main body 158a of the outer pipe 158.

[0079] The shaft 166 is provided with the valve body 572 formed in a position in which the gas chamber 568 is disposed, and the valve body 572 opens and closes a communication portion between the gas chamber 568 and the outer pipe 158 in response to the movement of the shaft 166.

[0080] In addition, the base end side (top side) of the inner pipe 156 has a taper surface 556b, and the outer diameter of the taper surface 556b is smaller than the inner diameter of the outer pipe 158. The taper surface 556b is provided with a communication hole 556c, and the inside of the main body 158a of the outer pipe 158 communicates with the inside of the main body 156a of the inner pipe 156 via the communication hole 556c.

[0081] As shown in FIG. 14B, when the valve body 572 is opened, the fuel gas guided to the inside of the main body 158a of the outer pipe 158 flows into the inside of the main body 156a of the inner pipe 156 via the communication hole 556c of the inner pipe 156.

[0082] The spring member 570 is disposed in the gas chamber 568. Thus, as shown in FIG. 14B, when the valve body 572 is opened, a bias force is applied to the valve body 572 in a direction in which the valve body 572 is closed, and thereby the movement of the shaft 166 is assisted by the hydraulic pressure.

[0083] As described above, in the fuel injecting unit 526, the injection of the fuel gas is stopped with the valve body 572, in addition to the cancel of the overlap between the inner holes 174 of the inner pipe 156 and the outer

holes 176 of the outer pipe 158. As a result, it is possible to prevent the fuel gas from leaking from the fuel injecting unit 526.

[0084] FIGS. 15A and 15B are views showing a fuel injecting unit 626 according to a fifth modification example. According to the fuel injecting unit 526 of the fourth modification example described above, the gas chamber 568 is disposed on the same side as the hydraulic chambers 160 and 162 with respect to the fuel pipe 152, and the inner pipe 156 and the valve body 572 move at the same time with the one shaft 166.

[0085] On the other hand, in the fifth modification example, as shown in FIGS. 15A and 15B, a shaft 666a fixed to the inner pipe 156 and the hydraulic piston 164 and a shaft 666b provided with a valve body 672 are separately provided. The shaft 666b, which is independent of the hydraulic piston 164, moves in the vertical direction in FIGS. 15A and 15B by a hydraulic mechanism (not shown), and opens or closes the valve body 672.

[0086] FIGS. 16A and 16B are views showing a fuel injecting unit 726 according to a sixth modification example. The fuel injecting unit 126 of the embodiment described above causes the inner pipe 156 to move with the hydraulic pressure. On the other hand, as shown in FIGS. 16A and 16B, in the sixth modification example, no hydraulic mechanism is installed.

[0087] A projecting portion 758a, which projects inwardly, is formed at the end portion of an outer pipe 758 on the upper side (upward in the stroke direction) in FIGS. 16A and 16B. The projecting portion 758a is disposed on the upper side in FIGS. 16A and 16B from the portion of the outer pipe 758, in which the inner pipe 756 is stowed. In addition, a part of the projecting portion 758a extends to the inner pipe 756 side, and is fit into a guide groove 756a formed in the inside of the inner pipe 756 on the upper side in FIGS. 16A and 16B. The projecting portion 758a and the guide groove 756a regulate the movement of the inner pipe 756 which rotates with respect to the outer pipe 758; however, the inner pipe 756 can move in the vertical direction in FIGS. 16A and 16B.

[0088] An end portion of the inner pipe 756 on the lower side is closed in FIGS. 16A and 16B, and one end of a spring member 770 (bias member) is fixed to the inner pipe 756 on the outer side. The other end of the spring member 770 is fixed to an adjustment member 780, the position of the adjustment member 780 is adjusted by fastening of a nut N, and thereby a position of the other end of the spring member 770 is adjusted in the stroke direction (direction of elastic deformation of the spring member 770).

[0089] The spring member 770 applies the bias force of pressing (biasing) the inner pipe 756 in a direction (here, the upper side in FIGS. 16A and 16B) parallel to a changing direction of a relative position with respect to the outer pipe 758.

[0090] In addition, a spring chamber 782, in which the spring member 770 is disposed, communicates with the scavenging chamber 120, and the inner pipe 756 is

pressed upward in FIGS. 16A and 16B with the pressure of the compressed active gas. On the other hand, the fuel gas is supplied to the inside of the inner pipe 756, and the inner pipe 756 is pressed downward in FIGS. 16A and 16B with the pressure of the fuel gas.

[0091] When, from the state shown in FIG. 16A, the inner pipe 756 is pressed in a direction (downward direction in FIGS. 16A and 16B) against the bias force of the spring member 770 and the pressing force due to the pressure of the active gas, with the pressure of fuel gas guided into the inner pipe 756, relative positions of the inner pipe 756 and the outer pipe 758 changes due to a change in pressure of the fuel gas as shown in FIG. 16B.

[0092] As described above, in the sixth modification example, the fuel injecting unit 726 does not need to be provided with the hydraulic mechanism, and thus it is possible to change the relative positions of the inner pipe 756 and the outer pipe 758 with the pressure of the fuel gas such that it is possible to reduce the costs.

[0093] As described above, the preferred embodiment of the present disclosure is described with reference to the accompanying figures; however, it is needless to say that the present disclosure is not limited to the embodiment. It is obvious for those skilled in the art to conceive various modification examples or alteration examples within the range of the claims, and thus it is understood that the examples are included within the technical scope of the present disclosure.

[0094] For example, in the embodiment and the modification example described above, the case where the inner pipes 156 and 756 are caused to move such that the relative positions of the inner pipes 156 and 756 and the outer pipes 158 and 758 change is described above. However, the outer pipes 158 and 758 may be caused to move such that the relative positions of the inner pipes 156 and 756 and the outer pipes 158 and 758 change.

[0095] In addition, in the third modification example, the case where one inner hole 474 and one outer hole 476 are provided is described above. However, as in the embodiment and the other modification examples described above, if the plurality of inner holes 174, 274, and 374 and the plurality of outer holes 176, 276, and 376 are provided to be separated from each other in the stroke direction, it is possible to reduce degradation of the strength of the inner pipes 156 and 756 and the outer pipes 158 and 758.

[0096] In addition, in the embodiment and the modification examples described above, the case where the driving unit 154 causes the inner pipes 156 and 756 to move in the stroke direction is described above. Although, the inner pipes 156 and 756 or the outer pipes 158 and 758 may be caused to rotate in a direction other than the stroke direction, for example, in the circumferential direction of the inner pipes 156 and 756. However, by moving the inner pipes 156 and 756 or the outer pipes 158 and 758 in the stroke direction, it is possible to simplify the structure and to reduce the costs.

[0097] Incidentally, the scavenging port has the degree

of opening that gradually increases in response to the movement of the piston to the bottom dead center side in the stroke direction, and then the degree of the opening is gradually decreases when the piston returns from the bottom dead center side to the top dead center side. In this manner, the flow quantity of the active gas suctioned in the cylinder from the scavenging port changes while the scavenging port is opened once depending on the change in the degree of the opening of the scavenging port. Nevertheless, as in Patent Document 1 described above, when fuel gas is injected with substantially a constant injection pressure during the opening of the scavenging port once, the mixture of the fuel gas and the active gas is likely to be locally lean or rich.

[0098] From such a situation, it is preferable to provide the uniflow scavenging two-cycle engine that is capable of achieving the evenness of the concentration of the fuel gas and the active gas which are suctioned while the scavenging port is opened once.

[0099] In order to solve the problem described above, there is provided a uniflow scavenging two-cycle engine including a cylinder in which a combustion chamber is formed, a piston that slides in the cylinder, a scavenging space which surrounds one end side of the cylinder in the stroke direction of the piston and to which compressed active gas is guided, a scavenging port that is provided in a portion positioned in the scavenging space in the cylinder, and that suctions active gas in the combustion chamber from the scavenging space in response to the sliding motion of the piston, a fuel injection opening that is provided on an outer side of the cylinder in a radial direction from the scavenging port injects fuel gas to active gas suctioned in the scavenging port, and an opening-closing mechanism that opens and closes the fuel injection opening depending on a pressure difference between a first position at which a pressure change is produced in proportion to the degree of opening of the scavenging port and a second position at which the pressure change is smaller than that at the first position.

[0100] In this manner, it is possible to achieve the evenness of the concentration of the fuel gas and the active gas which are suctioned while the scavenging port is opened once.

[0101] The first position may be positioned in the scavenging port.

[0102] The second position may be positioned to be farther separated from the scavenging port than the fuel injection opening.

[0103] The uniflow scavenging two-cycle engine may further include an inner pipe which has an inner hole penetrating between an inside and an outside thereof and through which fuel gas is guided to the inside, an outer pipe which has an outer hole penetrating between an inside and an outside thereof and stows the inner pipe in the inside thereof so as to form a double pipe with the inner pipe. The fuel injection opening may be formed by overlapping the inner hole and the outer hole, and an opening-closing mechanism may change relative posi-

tions of the inner pipe and the outer pipe with a pressing force due to the pressure difference, thereby changing an opening amount of the fuel injection opening.

[0104] When differential pressure between the second position and the first position increases, the inner pipe may be pressed to one end side in the stroke direction. When the differential pressure decreases, the inner pipe may be pressed to the other end side in the stroke direction.

[0105] Hereinafter, a preferred embodiment of the uniflow scavenging two-cycle engine described above will be described in detail with reference to the accompanying figures. The dimensions, the materials, the specific numbers other than the dimensions and the materials, or the like is provided only as an example for easy understanding of the disclosure, and the disclosure is not limited thereto except for a case where particular description is provided. Note that, in the following description, an element having substantially the same function and configuration is assigned with the same reference sign and a repeated description thereof is omitted, and illustration of an element without a direct relationship with the present disclosure is omitted in the figures.

[0106] FIG. 17 is a view showing an entire configuration of a uniflow scavenging two-cycle engine 1100.

[0107] The uniflow scavenging two-cycle engine 1100 of the embodiment is used in a ship or the like. Specifically, The uniflow scavenging two-cycle engine 1100 is configured to include a cylinder 1110, a piston 1112, an exhaust port 1114, an exhaust valve 1116, a scavenging port 1118, a scavenging reservoir (scavenging space) 1120, a scavenging chamber 1122 (scavenging space), a combustion chamber 1124, fuel pipes 1126, and an opening-closing mechanism 1128.

[0108] In the uniflow scavenging two-cycle engine 1100, exhaust, intake, compression, and combustion are performed during two strokes of an ascending stroke and a descending stroke of the piston 1112 and the piston 1112 slides in the cylinder 1110. One end of a piston rod 1112a is fixed to the piston 1112. In addition, a crosshead (not shown) is connected to the other end of the piston rod 1112a, and the crosshead reciprocates along with the piston 1112. When the crosshead reciprocates in response to the reciprocating of the piston 1112, a crankshaft (not shown) rotates by interlocking with the reciprocating.

[0109] The exhaust port 1114 is an opening provided in a cylinder head 1110a positioned above the top dead center of the piston 1112, and is opened and closed to discharge exhaust gas produced after combustion in the cylinder 1110. The exhaust valve 1116 slides vertically at a predetermined timing by an exhaust valve driving device 1116a and opens or closes the exhaust port 1114. When the exhaust port 1114 is opened, exhaust gas is discharged from the cylinder 1110 via the exhaust port 1114.

[0110] The scavenging port 1118 is a hole penetrating from an inner circumferential surface (inner circumferen-

tial surface of a cylinder liner 1110b) to an outer circumferential surface of the cylinder 1110 on the lower end side, and a plurality of scavenging ports are provided all around the cylinder 1110. The scavenging ports 1118 suction active gas in the cylinder 1110 in response to a sliding motion of the piston 1112. The active gas contains an oxidizing agent such as oxygen or ozone, or a mixture thereof (for example, air).

[0111] The active gas (for example, air) compressed by a blower (not shown) is sealed in the scavenging reservoir 1120, and the active gas is cooled by the cooler 1130. The compressed and cooled active gas is rectified by a current plate 1132 disposed in the scavenging reservoir 1120, and then moisture is removed by a drain separator 1134.

[0112] The scavenging chamber 1122 communicates with the scavenging reservoir 1120 and surrounds one end side (lower side in FIG. 17) of the cylinder 1110 in the stroke direction of the piston 1112 (hereinafter, simply abbreviated to a "stroke direction" in some cases), and active gas subjected to compression, cooling, and removal of moisture is guided thereto.

[0113] Here, the scavenging reservoir 1120 and the scavenging chamber 1122 configure the scavenging space. The scavenging space is a space to which the compressed active gas is guided and which surrounds the one end side (lower side in FIG. 17) of the cylinder 1110 in the stroke direction of the piston 1112. Here, as an example of the scavenging space, the scavenging reservoir 1120 and the scavenging chamber 1122 are described; however the scavenging space is not limited to the scavenging reservoir 1120 and the scavenging chamber 1122 as long as the scavenging space is a space to which the compressed active gas is guided and which surrounds the one end side of the cylinder 1110 in the stroke direction of the piston 1112.

[0114] The scavenging port 1118 is provided in a portion of the cylinder 1110 (cylinder liner 1110b) positioned in the scavenging chamber 1122, and suctions active gas from the scavenging chamber 1122 into the cylinder 1110 due to the differential pressure between the scavenging chamber 1122 and the cylinder 1110. The active gas suctioned in the cylinder 1110 is guided by the piston 1112 to the combustion chamber 1124 in response to the sliding motion of the piston 1112.

[0115] FIG. 18 is a sectional view taken along line II-II in FIG. 17. In FIG. 18, for easy understanding, a cross-sectional plane of the fuel pipe 1126 is shown in a simplified manner, and an internal configuration of the fuel pipe 1126 will be described below in detail. As shown in FIG. 18, the fuel pipe 1126 is provided on an outer side of the cylinder 1110 (cylinder liner 1110b) in the radial direction from the scavenging port 1118.

[0116] In an example shown in FIG. 18, the fuel pipe 1126 is disposed on the outer side of the outer surface of the cylinder 1110 in the radial direction between adjacent scavenging ports 1118, and thus the fuel pipe 1126 is unlikely to interfere with flowing of the active gas.

[0117] In the example shown in FIG. 18, a case, where the same number of the fuel pipes 1126 and the scavenging ports 1118 is disposed, is described; however, the number of the fuel pipes 1126 and the scavenging ports 1118 may be different from each other, or, for example, two scavenging ports 1118 may be provided for each of the fuel pipes 1126.

[0118] The fuel pipe 1126 is provided with annular pipe 1136 on the exhaust port 1114 side (upper side in FIG. 17). The annular pipe 1136 is a pipe that annularly surrounding the outer side of the cylinder 1110 in the radial direction, along the circumferential direction of the cylinder 1110 and communicates with the fuel pipe 1126. The fuel gas is guided to the annular pipe 1136 via the fuel injecting valve 1138 from a fuel tank 1140 in which the fuel gas is stored.

[0119] The annular pipe 1136 communicates with the fuel pipes 1126, respectively, the fuel injection opening, which will be described below, is formed in the fuel pipe 1126, the fuel gas flowing into the fuel pipe 1126 via the annular pipe 1136 from the fuel tank 1140 is injected into the active gas suctioned to the scavenging port 1118 from the fuel pipe 1126. As a result, the fuel gas and the active gas are suctioned in the cylinder 1110 through the scavenging port 1118 and are guided to the combustion chamber 1124.

[0120] In addition, as shown in FIG. 17, a pilot injection valve 1142 is provided in the cylinder head 1110a. An appropriate amount of fuel oil is injected from the pilot injection valve 1142 at a predetermined time point in an engine cycle. The fuel oil is vaporized with the heat in the combustion chamber 1124 and becomes the fuel gas. The fuel gas obtained by vaporization of the fuel oil spontaneously ignites, is combusted in a short time, and the temperature of the combustion chamber 1124 rises to be very high. As a result, it is possible to reliably combust the fuel gas guided to the combustion chamber 1124 from the scavenging port 1118 at a predetermined timing. The piston 1112 reciprocates using expansion pressure produced from the combustion of the fuel gas mainly guided from the scavenging port 1118.

[0121] Here, the fuel gas is generated, for example, by gasifying liquefied natural gas (LNG). In addition, the fuel gas is not limited to the LNG, and, for example, gas generated by gasifying liquefied petroleum gas (LPG), gas oil, heavy oil, or the like can be applied to the fuel gas.

[0122] FIG. 19 is an enlarged view of a portion in a dashed line in FIG. 17. As shown in FIG. 19, the fuel pipe 1126 is configured to have an inner pipe 1144 and an outer pipe 1146. The inner pipe 1144 communicates with the annular pipe 1136 via a communication passage 1148 on the upper side in FIG. 19, and the fuel gas is guided to the inside of the main body 1144a of the inner pipe 1144 from the annular pipe 1136. The outer pipe 1146 stows the inner pipe 1144 inside the main body 1146a and forms a double pipe with the inner pipe 1144.

[0123] The inner pipe 1144 has inner holes 1150 communicating from the inside to the outside of the main body

1144a, and the outer pipe 1146 has outer holes 1152 communicating from the inside to the outside of the main body 1146a. The inner pipe 1144 has a front end on the lower side in FIG. 19, which is closed, and the fuel gas guided to the inside of the main body 1144a of the inner pipe 1144 remains inside the main body 1144a until the inner holes 1150 and the outer holes 1152 overlap each other. When the inner holes 1150 and the outer holes 1152 overlap each other, the fuel gas is injected to the outside of the fuel pipe 1126 through the inner holes 1150 and the outer holes 1152.

[0124] In other words, the inner holes 1150 and the outer holes 1152 overlap each other, and thereby the fuel injection opening 1154 that injects the fuel gas into the active gas suctioned in the scavenging port 1118 is formed. As described above, since the fuel pipe 1126 is provided on the outer side of the cylinder 1110 in the radial direction from the scavenging port 1118, the fuel injection opening 1154 formed in the fuel pipe 1126 is also provided on the outer side of the cylinder 1110 in the radial direction from the scavenging port 1118.

[0125] The opening-closing mechanism 1128 changes the relative positions of the inner pipe 1144 and the outer pipe 1146 in the stroke direction (vertical direction in FIG. 19) of the piston 1112, the inner hole 1150 and the outer hole 1152 are caused to overlap each other, and thereby the fuel injection opening 1154 is opened. The overlap is cancelled, and thereby the fuel injection opening 1154 is closed.

[0126] Specifically, the opening-closing mechanism 1128 has a main body 1128a fixed to the front end side (lower side in FIG. 19, and the bottom dead center side of the piston 1112) of the outer pipe 1146. The main body 1128a is provided with a spring member 1156 in the inside thereof.

[0127] One end of the spring member 1156 abuts on the front end portion of the inner pipe 1144, and the other end thereof abuts on a partition wall 1158 formed in the main body 1128a. The spring member 1156 applies a bias force of pressing the inner pipe 1144 to the top dead center side of the piston 1112.

[0128] In addition, two pressure chambers 1160 and 1162 are provided inside the main body 1128a on the top and bottom dead center side from the spring member 1156. The two pressure chambers 1160 and 1162 are provided to be continuous in the stroke direction of the piston 1112, and are partitioned with a partition member 1164 that is elastically deformed due to the pressure difference between the two pressure chambers 1160 and 1162.

[0129] One end of a shaft 1166 is fixed to the partition member 1164, and the other end of the shaft 1166 penetrates the partition wall 1158, projects to the spring member 1156 side, and faces the front end portion of the inner pipe 1144. The other end of the shaft 1166 presses the front end of the inner pipe 1144 due to the pressure difference between the two pressure chambers 1160 and 1162 in response to elastic deformation of the partition member 1164, and the inner pipe 1144 is pressed to the

top dead center side.

[0130] The pressure chamber 1160 on the bottom dead center side is provided with a spring member 1168 between the partition member 1164 and the main body 1128a, and the spring member 1168 applies a bias force of pressing the partition member 1164 to the top dead center side, thereby supporting the partition member 1164.

[0131] Communication piping 1170 is connected to the pressure chamber 1160 on the bottom dead center side. In addition, the cylinder 1110 is provided with a through-hole 1110c formed to penetrate through the cylinder 1110 from the outer circumferential surface to the scavenging port 1118. The communication piping 1170 and the through-hole 1110c are connected, and the inside (first position) of the scavenging port 1118 communicates with the pressure chamber 1160 via the communication piping 1170 and the through-hole 1110c.

[0132] On the other hand, piping (not shown) is connected to the pressure chamber 1162 on the top dead center side, the pressure chamber 1162 communicates, via the piping, with a position farther separated from the scavenging port 1118 than the fuel injection opening 1154, such as a position (second position) of the scavenging reservoir 1120, at which the active gas less flows. The second position has a small pressure change of static pressure to the extent that the active gas less flows than at the first position.

[0133] FIG. 20 is a view showing the fuel pipe 1126 and the opening-closing mechanism 1128 in FIG. 19. As shown in FIG. 20, the plurality of inner holes 1150 and outer holes 1152 are provided to be separated from one another in the stroke direction, and are provided at an equal interval in the stroke direction. In addition, the inner holes 1150 and the outer holes 1152 have the same shape in the cross-sectional plane of which normal axis is perpendicular to the penetrating direction.

[0134] In FIG. 20, the base end side (top dead center side) of the inner pipe 1144 abuts on a positioning member 1172. Hence, the relative positions of the inner pipe 1144 with respect to the outer pipe 1146 do not move to the top dead center side from a position shown in FIG. 20.

[0135] In addition, the movement of the inner pipe 1144 to the bottom dead center side is regulated to a position at which the front end side of the inner pipe 1144 abuts on the main body 1128a of the opening-closing mechanism 1128. Therefore, a movable distance of the inner pipe 1144 in the stroke direction is a length represented by reference sign M in FIG. 20.

[0136] In FIG. 20, when the inner pipe 1144 relatively move to the bottom dead center side with respect to the outer pipe 1146 by the distance M, that is, when the inner pipe 1144 moves to the bottom dead center side, a positional relationship, in which the inner holes 1150 and the outer holes 1152 completely overlap each other, is obtained.

[0137] FIGS. 21A to 21C are views showing opening and closing of the fuel injection opening 1154. As shown

in FIG. 21A, when the inner pipe 1144 is positioned to be closest to the top dead center side, the inner holes 1150 and the outer holes 1152 do not overlap each other, and the fuel injection opening 1154 is completely closed.

[0138] When the piston 1112 moves from the top dead center side to the bottom dead center side, the scavenging port 1118 starts to be opened, and the active gas starts to be suctioned from the scavenging port 1118 into the cylinder 1110, dynamic pressure in the scavenging port 1118 increases and the static pressure therein decreases. As a result, pressure of the pressure chamber 1160 starts to decrease, and the inner pipe 1144 moves to the bottom dead center side as shown in FIG. 21B. At this time, the inner holes 1150 and the outer holes 1152 partially overlap each other, and a part of the fuel injection opening 1154 is opened.

[0139] Further, when the scavenging port 1118 is fully opened, a flow rate of the active gas suctioned from the scavenging port 1118 into the cylinder 1110 increases, the dynamic pressure in the scavenging port 1118 increases, the static pressure therein remarkably decreases, and the pressure of the pressure chamber 1160 further decreases. As a result, as shown in FIG. 21C, the inner pipe 1144 moves to be closest to the bottom dead center side and the inner holes 1150 and the outer holes 1152 completely overlap each other. In other words, the fuel injection opening 1154 is fully opened.

[0140] When the piston 1112 returns at the bottom dead center and moves toward the top dead center side, the inner pipe 1144 moves to the top dead center side in proportion to the opening of the scavenging port 1118, from a state shown in FIG. 21C to a state shown in FIG. 21A.

[0141] FIGS. 22A and 22B are diagrams showing a relationship between a degree of opening of the scavenging port 1118 and a concentration of mixture. In FIGS. 22A and 22B, the vertical direction represents the stroke direction of the piston 1112, the upper side corresponds to the top dead center side of the piston 1112, and the lower side corresponds to the bottom dead center side of the piston 1112.

[0142] The scavenging port 1118 has an opening area which changes depending on the position of the piston 1112 as shown in the graph of the opening area of the port in FIGS. 22A and 22B. When the scavenging port 1118 starts to be opened, the scavenging port 1118 starts to be opened from a portion thereof on the top dead center side of the piston 1112, finally, to a portion thereof on the bottom dead center side. When the scavenging port 1118 starts to be closed, the scavenging port 1118 starts to be closed from the portion thereof on the bottom dead center side of the piston 1112, finally, to the portion thereof on the top dead center side.

[0143] As a result, a scavenging air amount (scavenging active gas amount) changes in proportion to an opening area of the port, as shown in the graph of the scavenging air amount in FIGS. 22A and 22B. At this time, in a comparative example shown in FIG. 22B, an injection

amount of the fuel gas is not proportional to the opening area of the port, as shown in the graph of the gas injection amount. Therefore, as shown in the graph of the concentration of mixture in FIG. 22B, the concentration of mixture of the fuel gas and the active gas from the scavenging port 1118 is likely to be locally rich.

[0144] Incidentally, as described above, since the static pressure in the scavenging port 1118 decreases depending on the scavenging air amount, a pressure difference ΔP between the inside (first position) of the scavenging port 1118 and the scavenging reservoir 1120 (second position) increases, as shown in FIG. 22A.

[0145] In the embodiment, the opening-closing mechanism 1128 is provided to cause the relative position of the inner pipe 1144 to automatically shift with respect to the outer pipe 1146 depending on the pressure difference ΔP , and also changes the opening area of the fuel injection opening 1154 shown in the graph of the opening area of injection opening in FIG. 22A, depending on the opening area of the scavenging port 1118.

[0146] Therefore, as shown in a graph of a gas injection amount in FIG. 22A, since the injection amount of the fuel gas increases and decreases substantially in proportional to the amount of the active gas, it is possible to maintain a substantially constant concentration of mixture of the fuel gas and the active gas that flows in from the scavenging port 1118.

[0147] In the embodiment described above, the case where the pressure difference between the first position and the second position is changed into the pressing force, and the opening-closing mechanism 1128 opens or closes the fuel injection opening 1154 is described above; however, for example, the pressure difference between the first position and the second position may be acquired as an electric signal, and the opening-closing mechanism 1128 may open or close the fuel injection opening 1154 with an actuator depending on the pressure difference between the first position and the second position.

[0148] In addition, in the embodiment described above, the case where the first position is positioned in the scavenging port 1118 is described above; however, the first position may be positioned in any portion other than the scavenging port 1118, as long as the pressure change is produced at the position depending on the degree of the opening of the scavenging port 1118. However, the first position is disposed in the scavenging port 1118, and thereby the pressure change depending on the degree of the opening of the scavenging port 1118 is reflected to the degree of the opening of the fuel injection opening 1154 with high accuracy.

[0149] In addition, in the embodiment described above, the case where the second position is positioned to be farther separated from the scavenging port 1118 than from the fuel injection opening 1154 is described above; however, the second position may be positioned in any position, as long as the pressure change is smaller than at the first position. Here, when the second position

is positioned to be farther separated from the scavenging port 1118, such as the scavenging reservoir 1120, than from the fuel injection opening 1154, the second position is unlikely to receive an effect of the flow of the active gas that is suctioned in the scavenging port 1118 and the pressure change is reduced such that it is possible to appropriately perform the opening and closing of the fuel injection opening 1154.

[0150] In addition, in the embodiment described above, the case where the double pipe configured to have the inner pipe 1144 and the outer pipe 1146 is provided, and the fuel injection opening 1154 is formed in proportion to the overlap between the inner holes 1150 and the outer holes 1152 is described above. Although, the double pipe is not included in the necessary configuration, and the fuel injection opening 1154 may be opened or closed by another opening-closing mechanism depending on the pressure difference between the first position and the second position. However, the double pipe is configured to have the inner pipe 1144 and the outer pipe 1146, and thereby it is possible to open or close the fuel injection opening 1154 with a simple mechanism.

[0151] In addition, in the embodiment described above, when the differential pressure between the scavenging reservoir 1120 (second position) and the scavenging port 1118 (first position) increases, the inner pipe 1144 is pressed to the one end side (bottom dead center side) in the stroke direction. When the differential pressure decreases, of the inner pipe 1144 is pressed to the other end side (top dead center side) in the stroke direction is described above. However, on the contrary, when the differential pressure between the scavenging reservoir 1120 (second position) and the scavenging port 1118 (first position) increases, the inner pipe 1144 may be pressed to the top dead center side in the stroke direction. In this case, when the differential pressure decreases, the inner pipe 1144 is pressed to the bottom dead center side in the stroke direction.

[0152] However, when the inner pipe 1144 is configured to be pressed in the orientation of the embodiment described above, a portion in which the outer hole 1152 and the inner hole 1150 start to overlap each other is the top dead center side of one outer hole 1152. Since a portion the scavenging port 1118, in which the scavenging port starts to open, is also the top dead center side, it is possible to start the injection of the fuel gas from the side close to the active gas that flows in the scavenging port 1118 that starts to be opened such that an effect is achieved in that the fuel gas is less locally rich or lean.

Industrial Applicability

[0153] According to the present disclosure, it is possible to use to a uniflow scavenging two-cycle engine that fuel gas along with active gas are suctioned from a scavenging port into a cylinder.

Reference Signs List

[0154]

- Ob large-flow-quantity opening region
- Os small-flow-quantity opening region
- 100 uniflow scavenging two-cycle engine
- 110 cylinder
- 112 piston
- 118 scavenging port
- 126 fuel injecting unit
- 154 driving unit
- 156,756 inner pipe
- 158,758 outer pipe
- 174,274,374,474 inner hole
- 176,276,376,476 outer hole
- 526, 626, 726 fuel injecting unit
- 770 spring member (bias member)

Claims

1. A uniflow scavenging two-cycle engine comprising:

- a cylinder in which a combustion chamber is formed;
- a piston that slides in the cylinder;
- a scavenging port that is provided one end side of the piston in a stroke direction in the cylinder and suctions active gas in the combustion chamber in response to a sliding motion of the piston; and
- a fuel injecting unit that is provided on an outer side of the cylinder in a radial direction from the scavenging port and injects fuel gas into the active gas which is suctioned into the scavenging port, wherein the fuel injecting unit includes:
 - an inner pipe which has an inner hole penetrating between an inside and an outside thereof and through which fuel gas is guided to the inside,
 - an outer pipe which has an outer hole penetrating between an inside and an outside thereof and stows the inner pipe in the inside thereof so as to form a double pipe with the inner pipe, and
 - a driving unit which changes relative positions of the inner pipe and the outer pipe and changes an opening amount as an area of an overlap between the inner hole and the outer hole.

- 2. The uniflow scavenging two-cycle engine according to Claim 1, wherein an opening region formed of the overlap between the inner hole and the outer hole includes a

small-flow-quantity opening region that is positioned relatively on one end side in the stroke direction and a large-flow-quantity opening region that is positioned on the other end side in the stroke direction from the small-flow-quantity opening region.

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due to a change in pressure of the fuel gas.

3. The uniflow scavenging two-cycle engine according to Claim 2,
wherein a plurality of the inner holes and a plurality of the outer holes are provided to be separated in the stroke direction, respectively, and the inner holes and the outer holes, which form the large-flow-quantity opening region, are separated in the stroke direction from the inner holes and the outer holes, which form the small-flow-quantity opening region, respectively. 10 15
4. The uniflow scavenging two-cycle engine according to Claim 2 or 3,
wherein the large-flow-quantity opening region is configured to have a state in which the inner hole and the outer hole overlap each other for a longer time than the small-flow-quantity opening region. 20
5. The uniflow scavenging two-cycle engine according to any one of Claims 2 to 4,
wherein the large-flow-quantity opening region is configured such that the inner hole and the outer hole overlap each other earlier than the small-flow-quantity opening region. 25 30
6. The uniflow scavenging two-cycle engine according to any one of Claims 2 to 5,
wherein the large-flow-quantity opening region is configured such that the overlap between the inner holes and the outer holes is released later than the small-flow-quantity opening region. 35
7. The uniflow scavenging two-cycle engine according to any one of Claims 2 to 6,
wherein the opening amount of the large-flow-quantity opening region is larger than the opening amount of the small-flow-quantity opening region. 40
8. The uniflow scavenging two-cycle engine according to any one of Claims 1 to 7,
wherein the driving unit causes the inner pipe or the outer pipe to move in the stroke direction. 45
9. The uniflow scavenging two-cycle engine according to any one of Claims 1 to 8,
wherein the driving unit has a bias member that biases the inner pipe in a direction parallel to a changing direction of the relative positions, and
wherein, when the inner pipe is pressed in a direction against a bias force of the bias member with pressure of fuel gas guided into the inner pipe, relative positions of the inner pipe and the outer pipe changes 50 55

FIG. 1

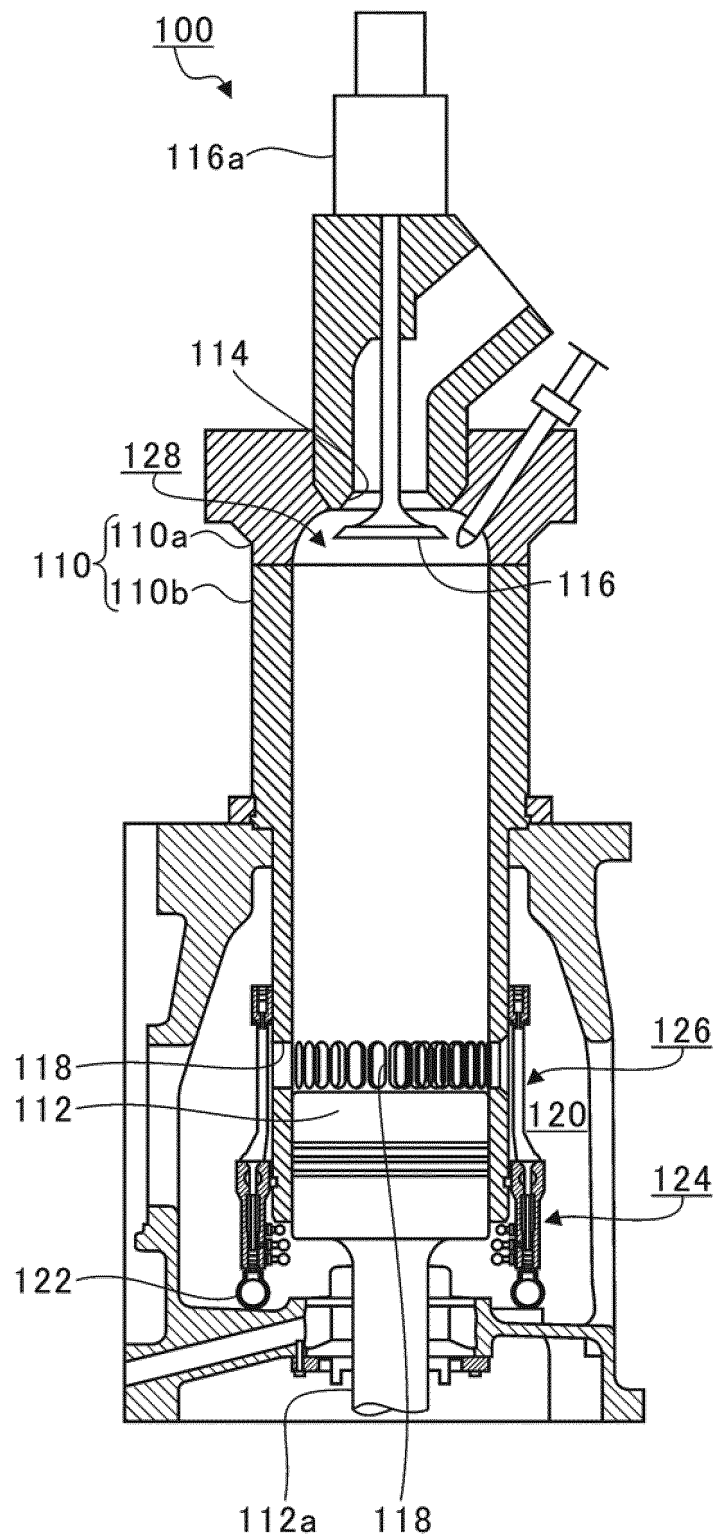


FIG. 2

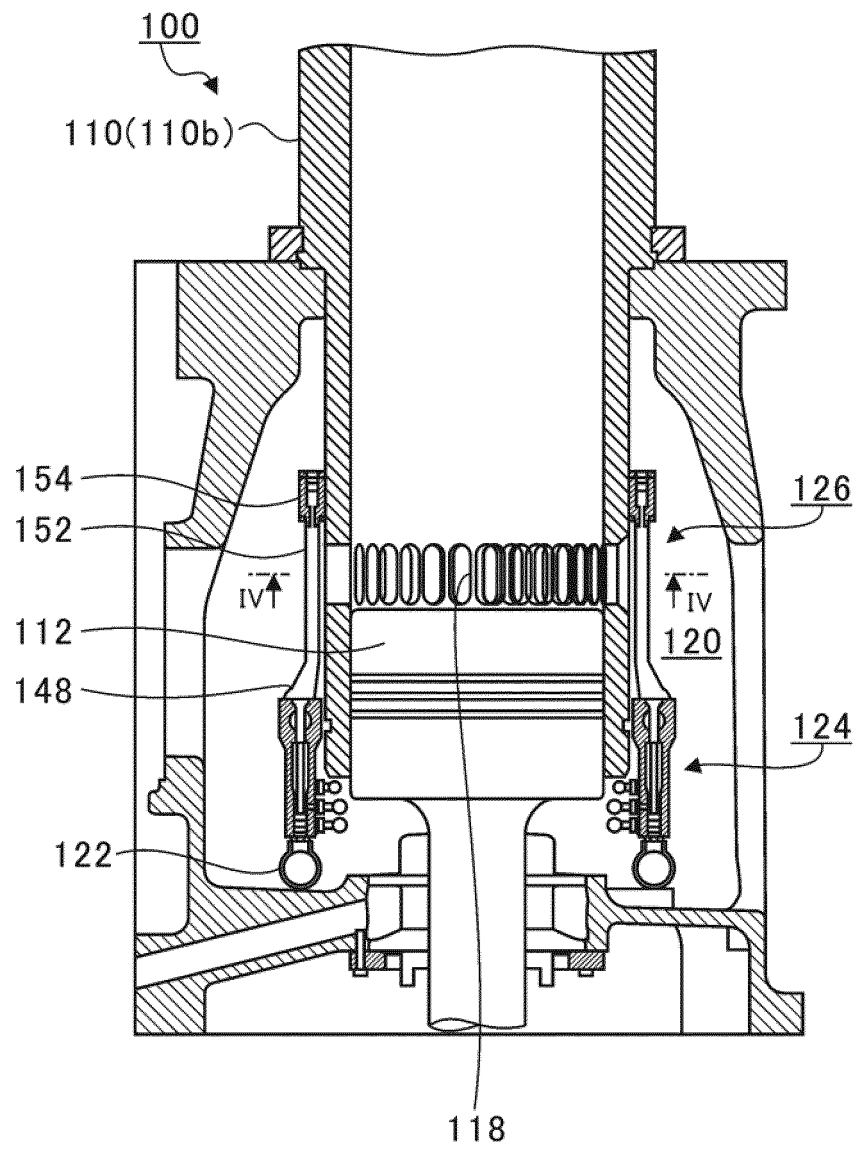


FIG. 3

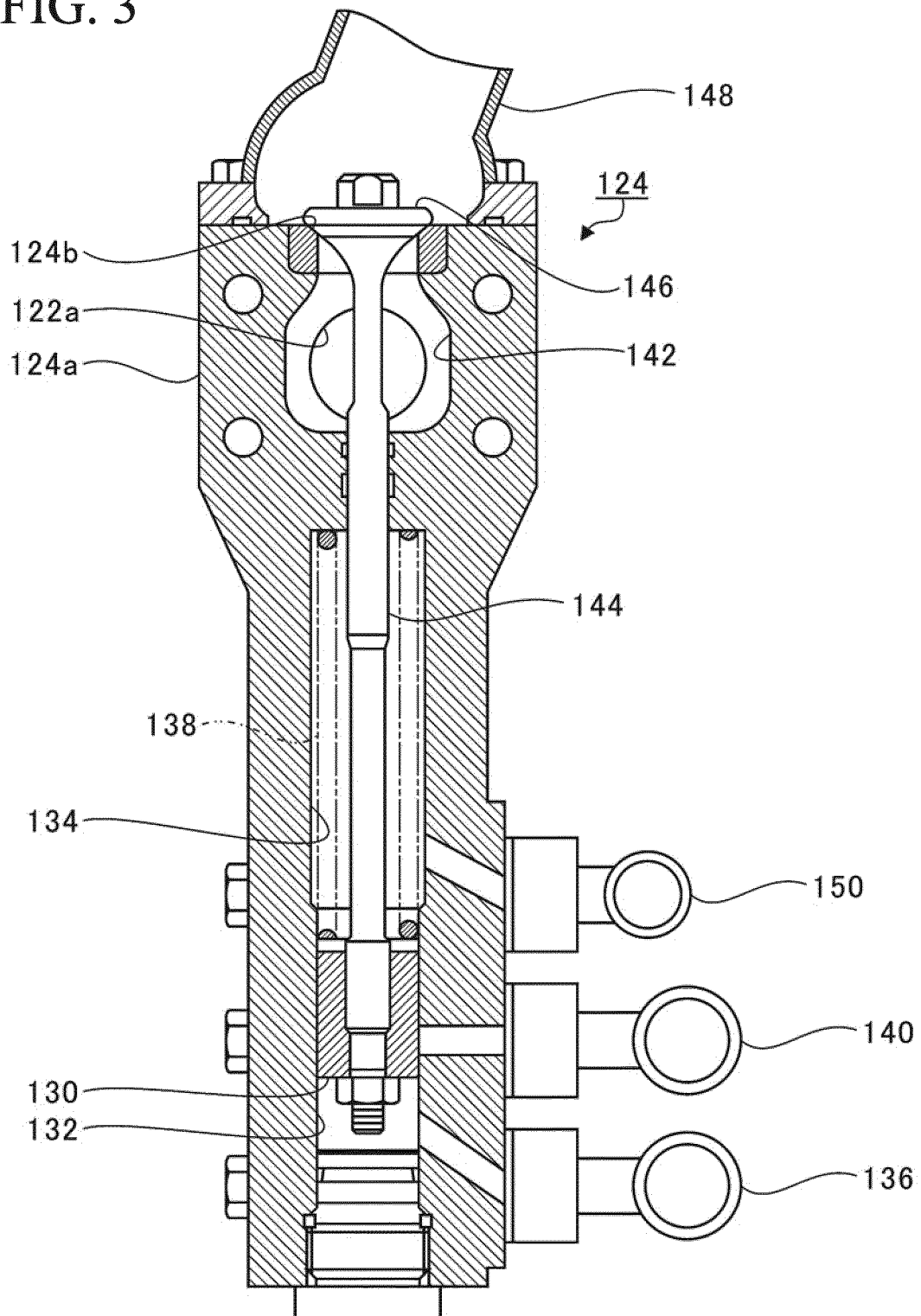


FIG. 4

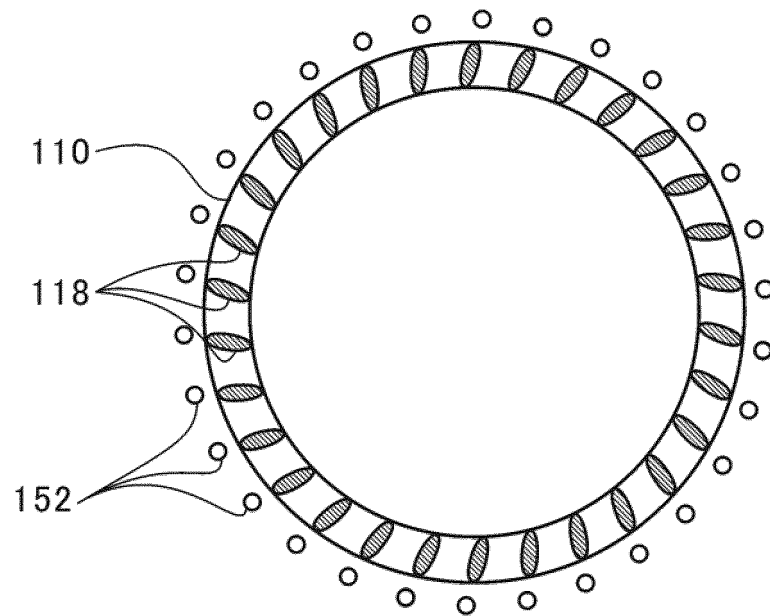


FIG. 5A

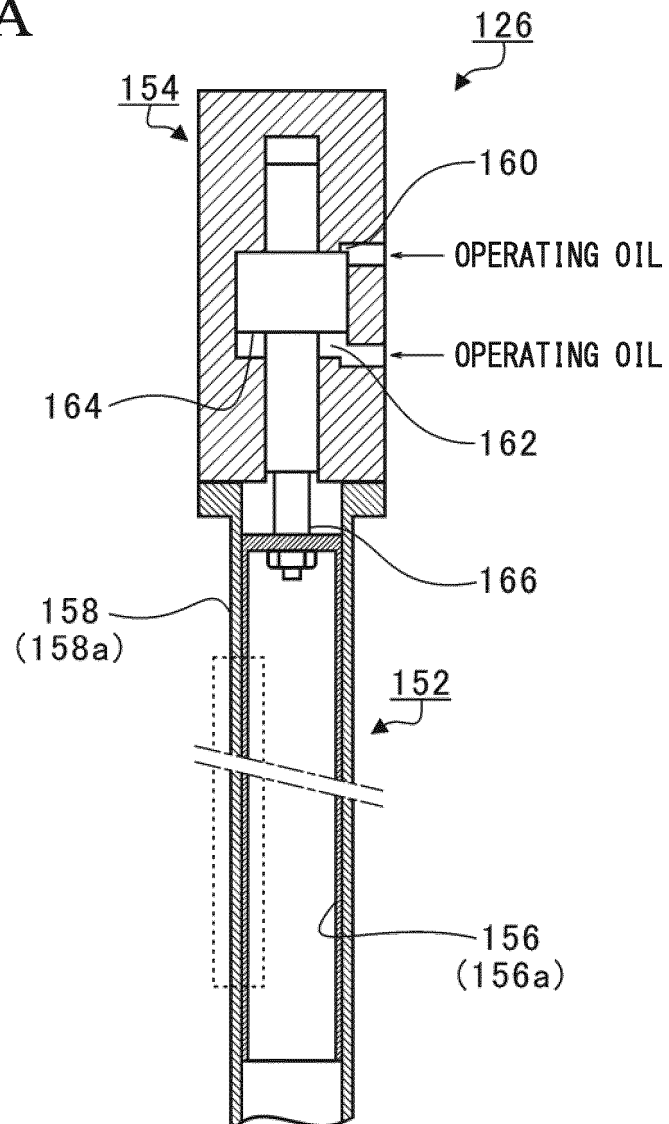


FIG. 5B

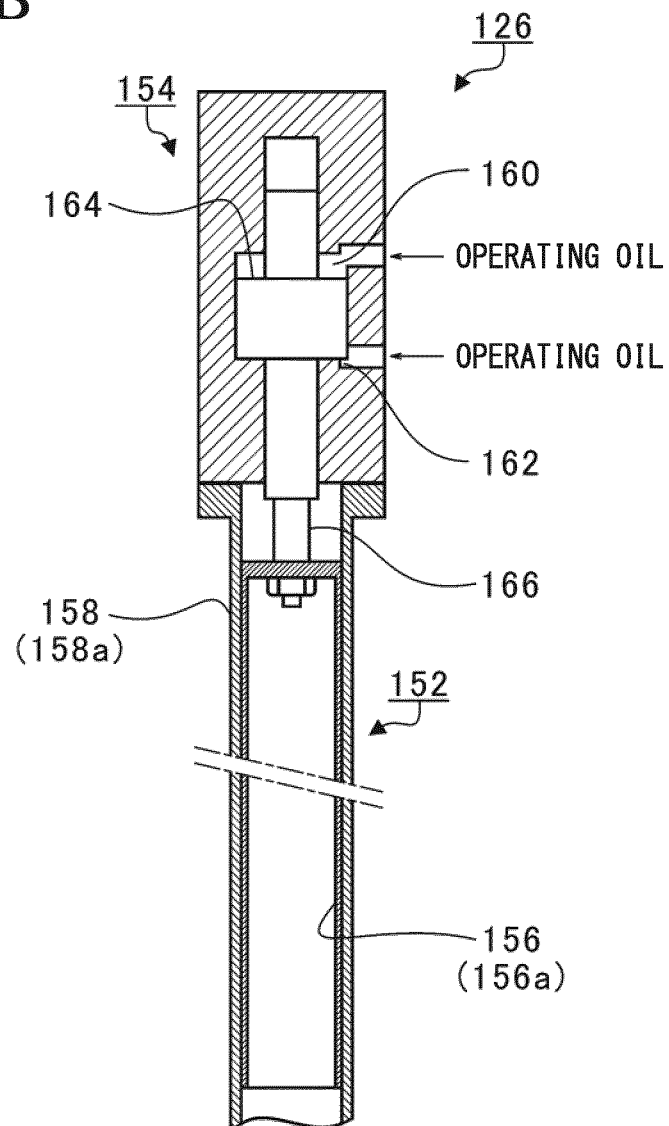


FIG. 6A

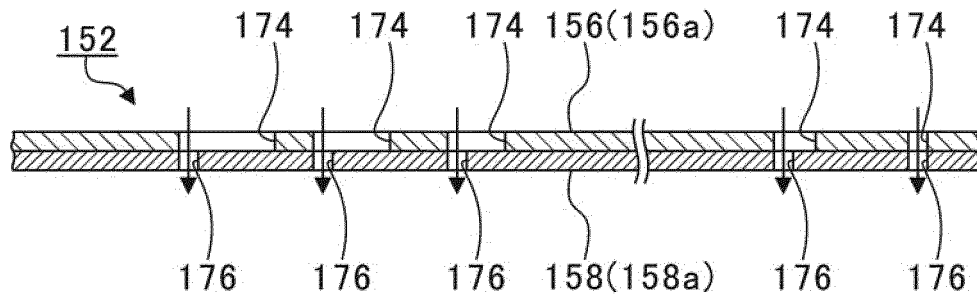


FIG. 6B

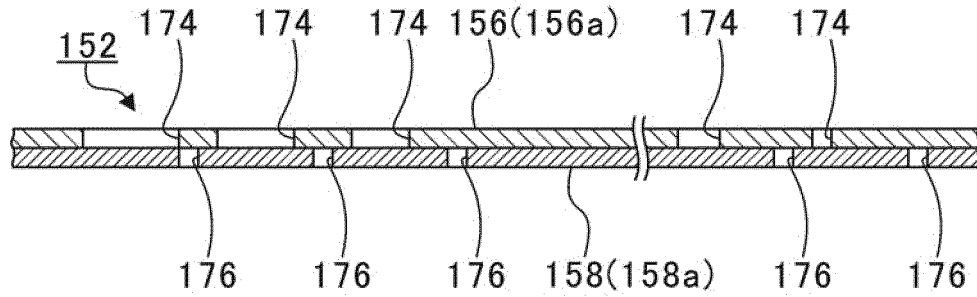


FIG. 7

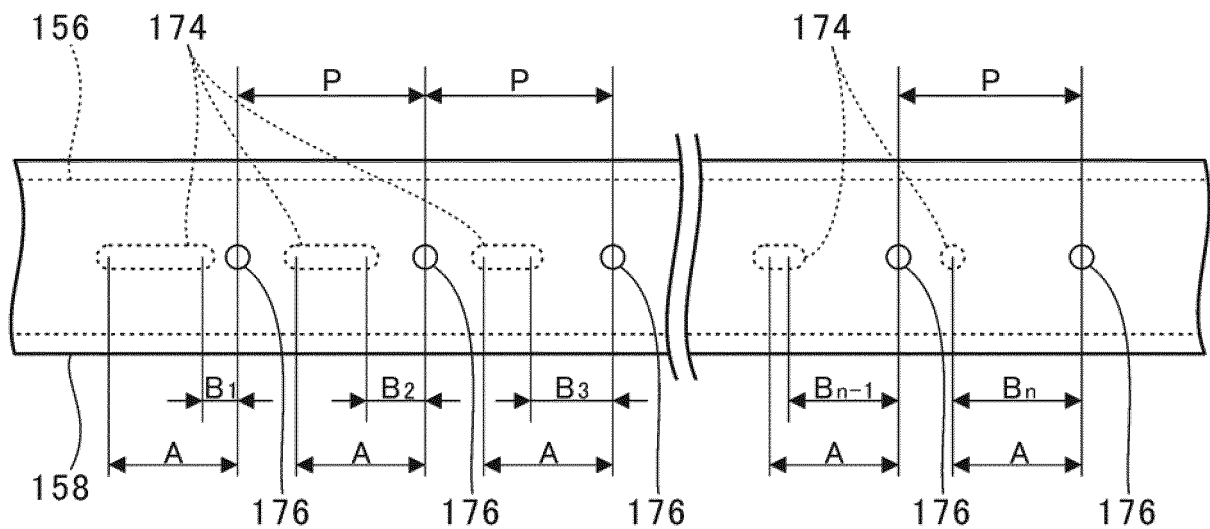


FIG. 8

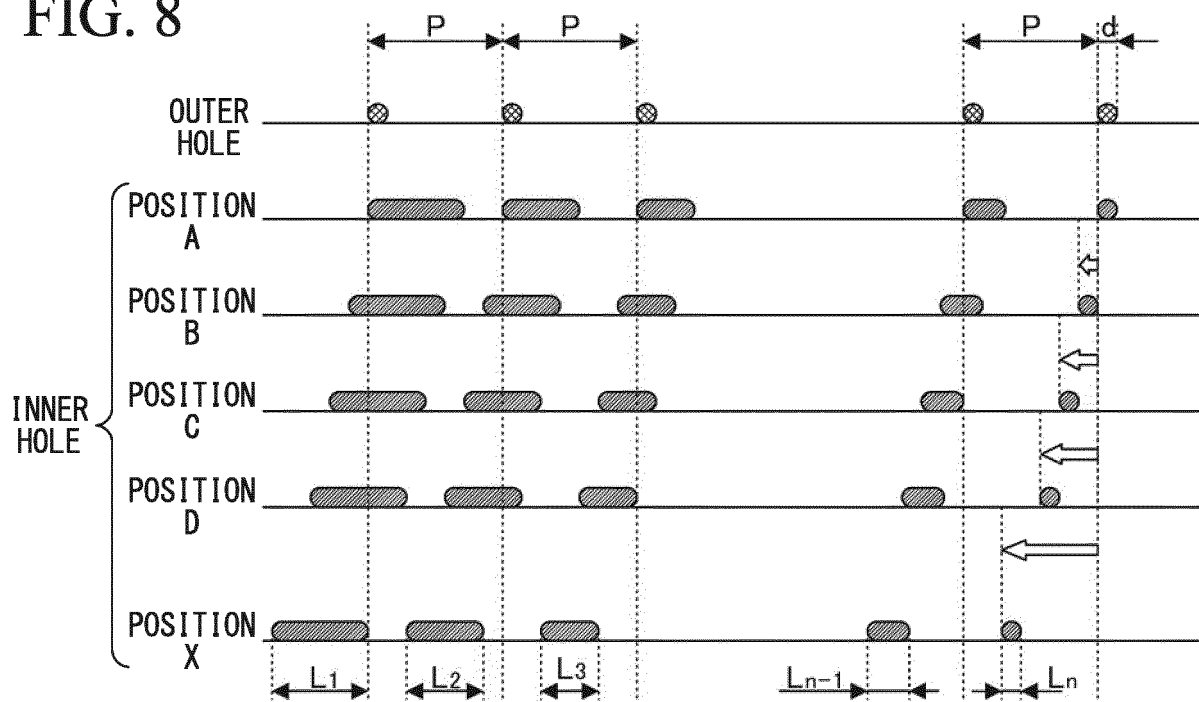


FIG. 9A

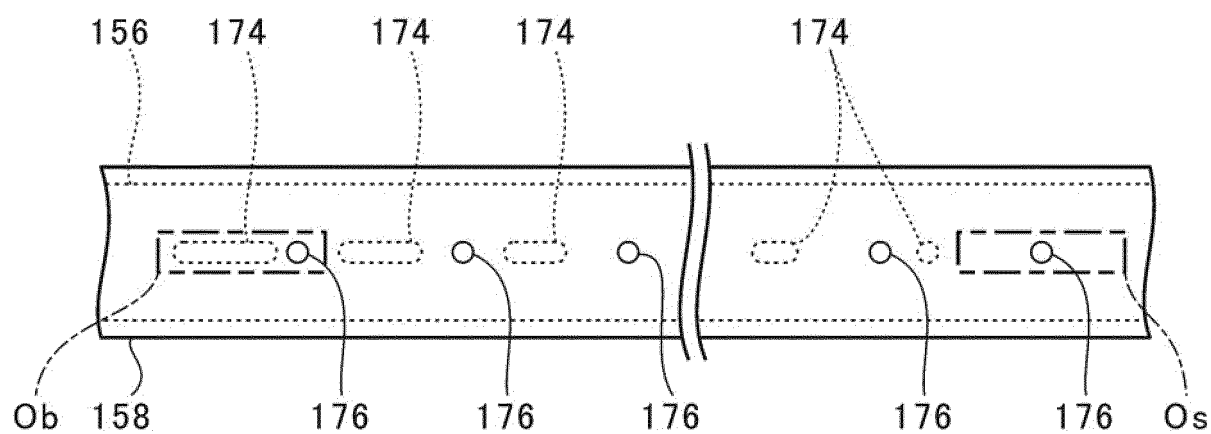


FIG. 9B

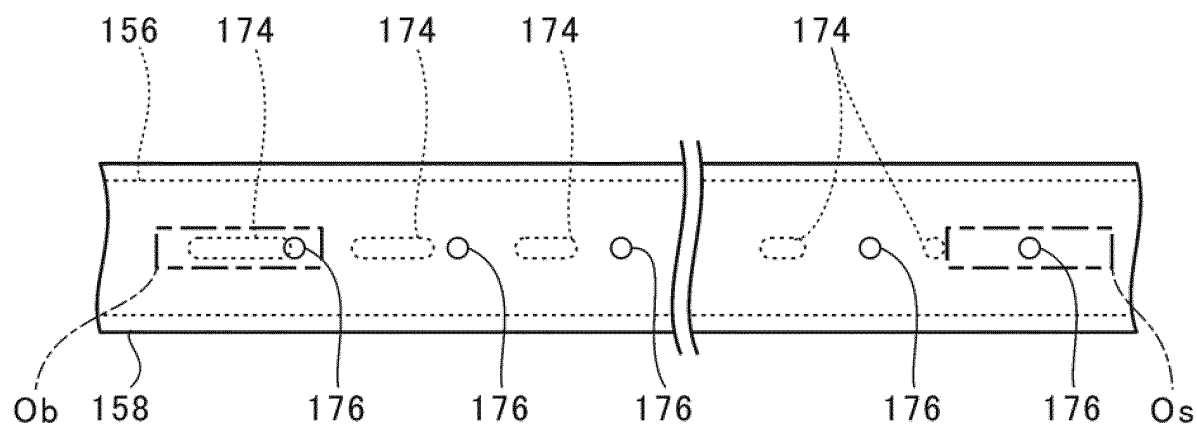


FIG. 9C

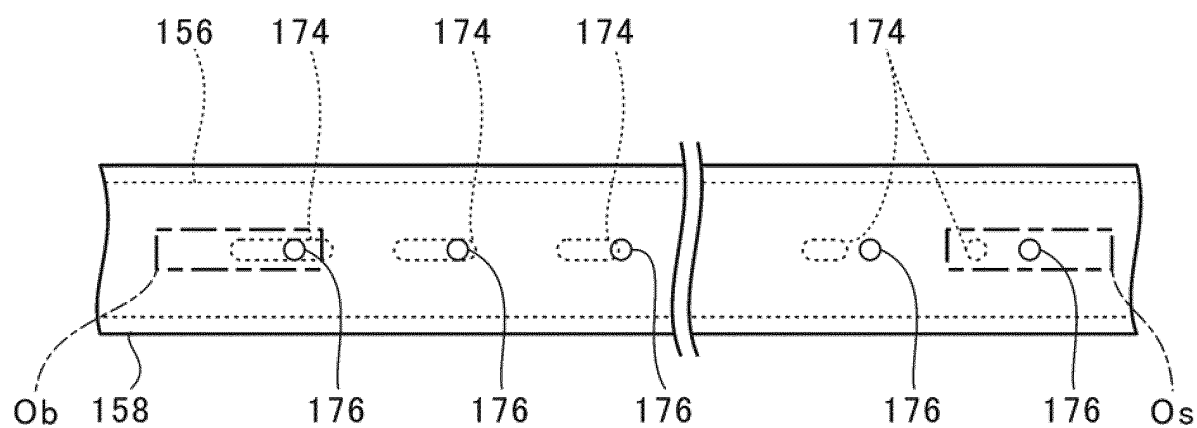


FIG. 9D

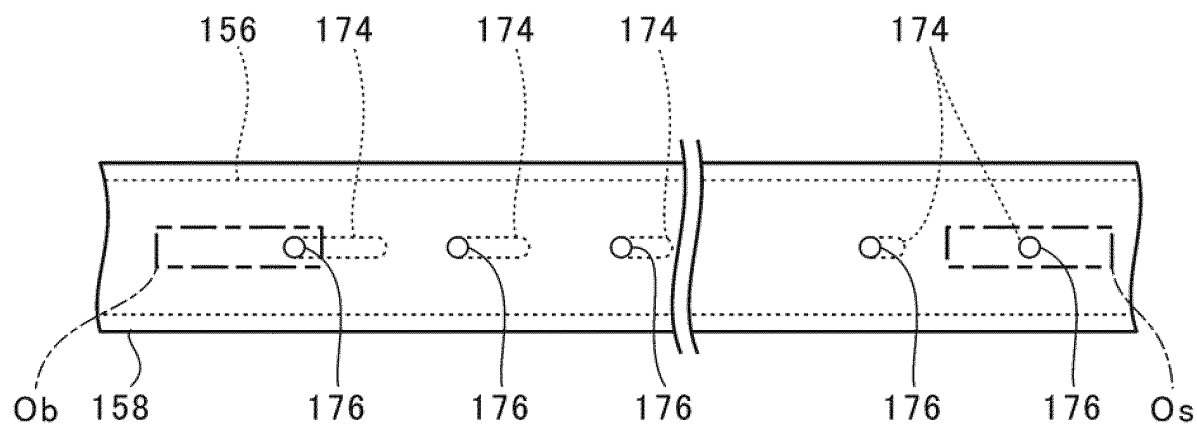


FIG. 10A

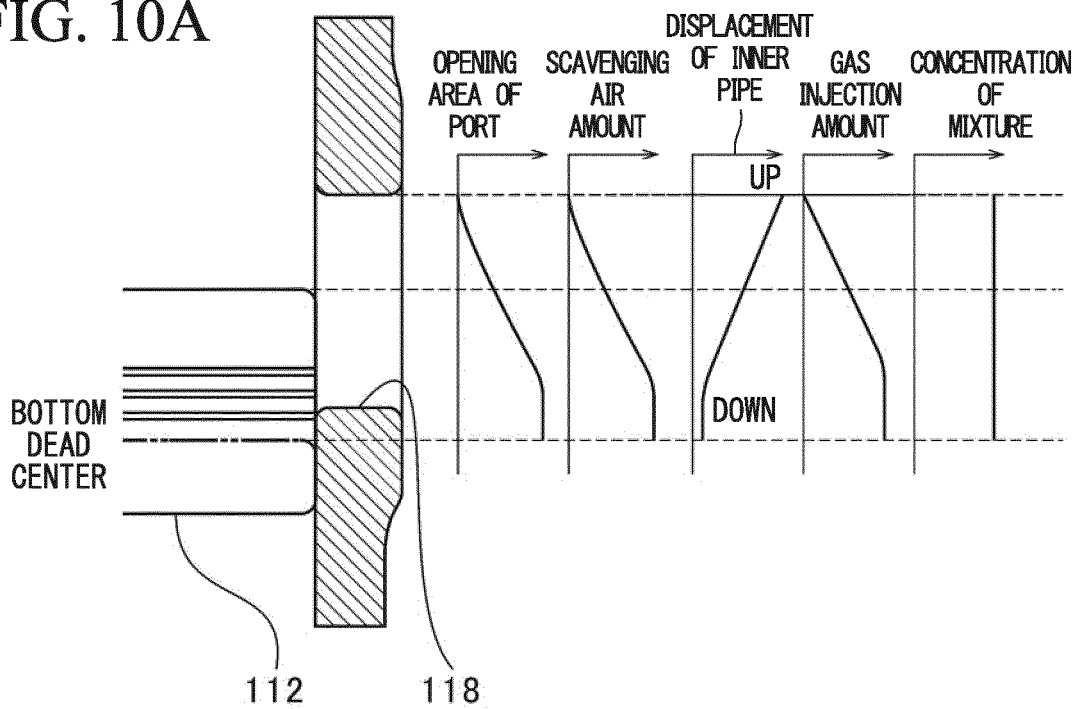


FIG. 10B

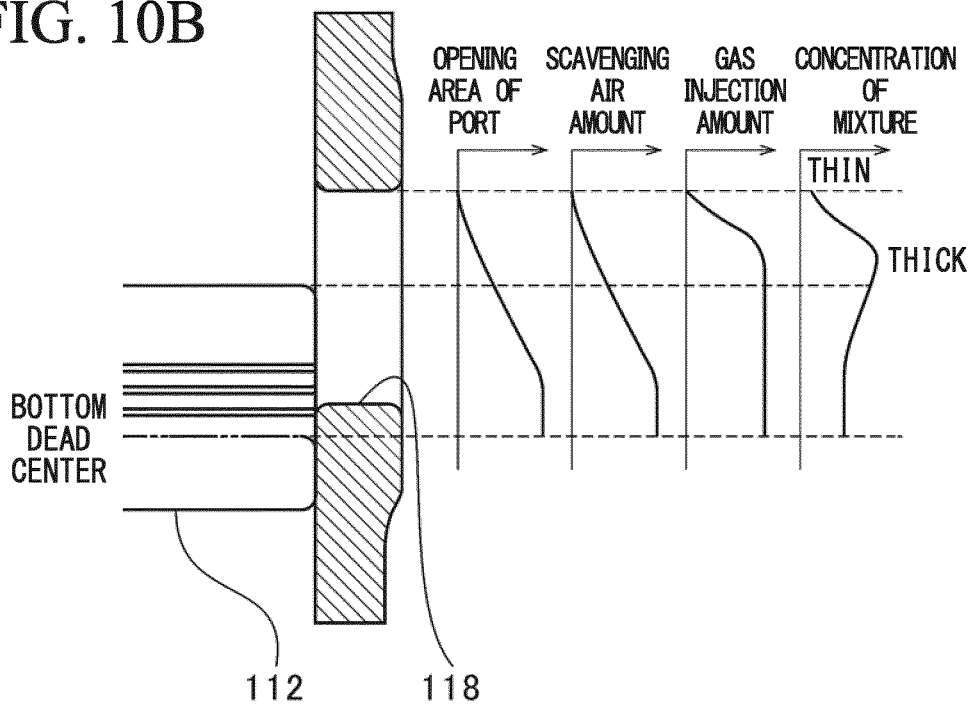


FIG. 11A

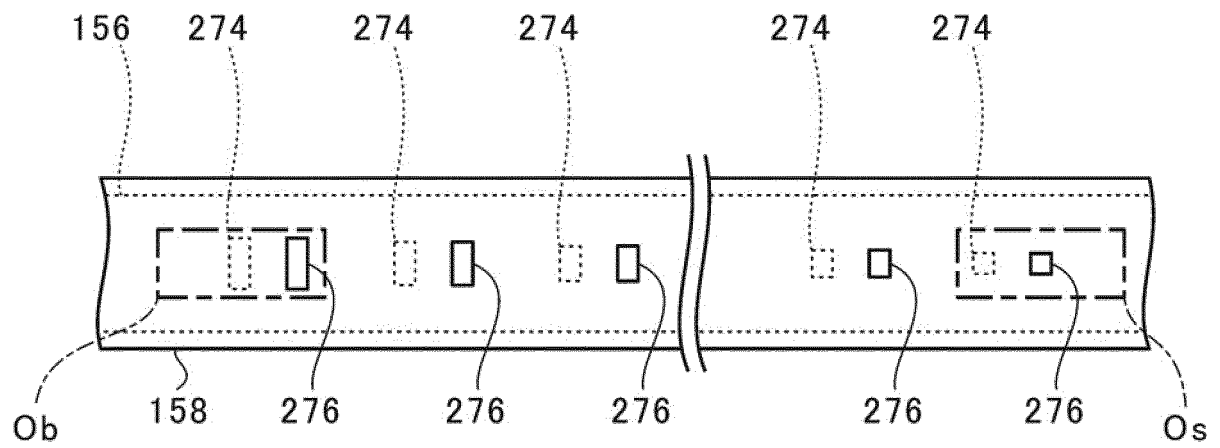


FIG. 11B

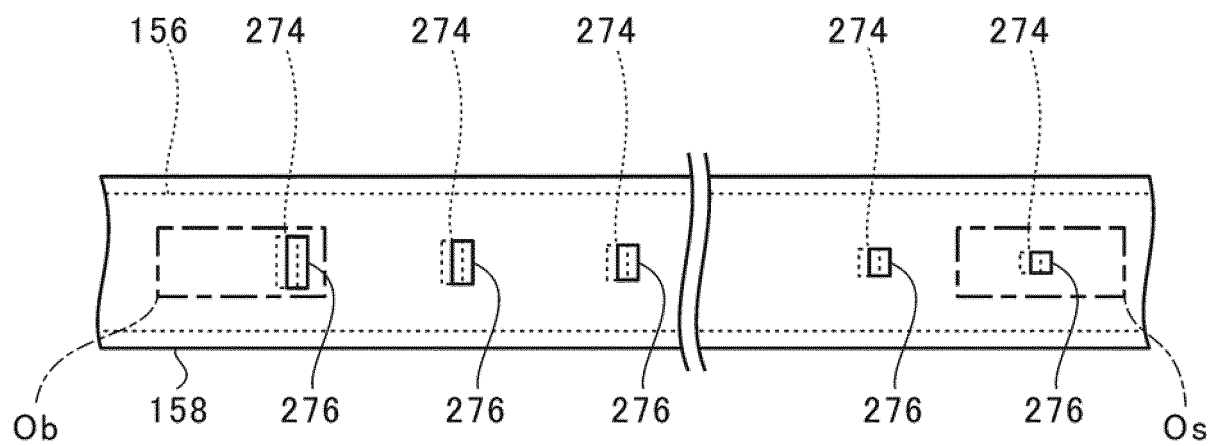


FIG. 12A

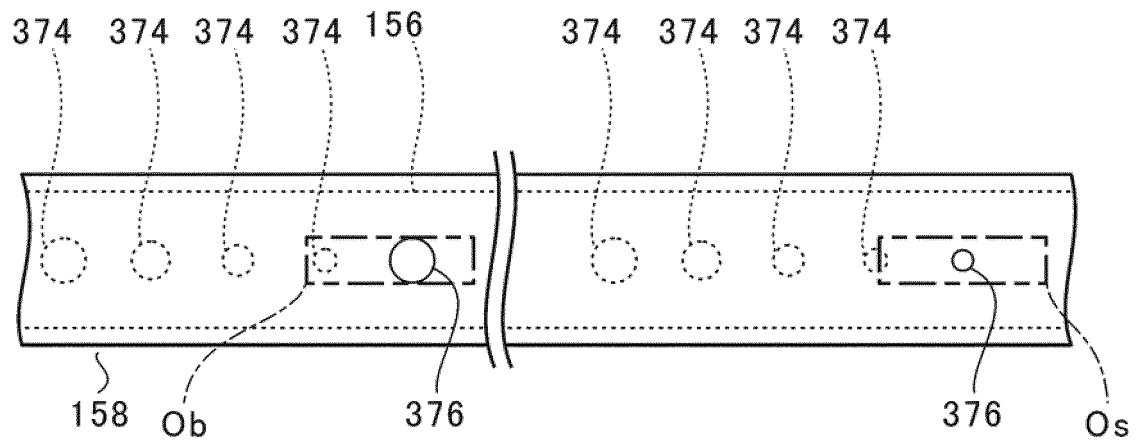


FIG. 12B

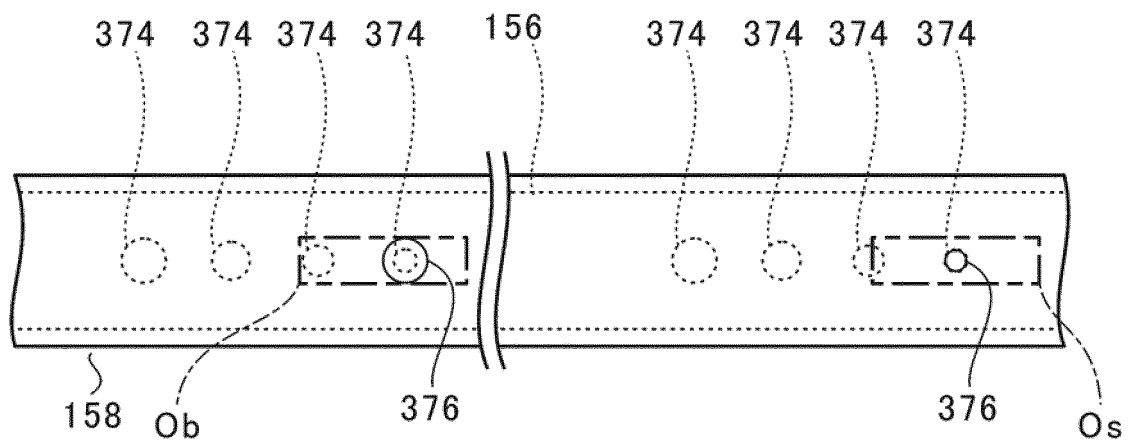


FIG. 13A

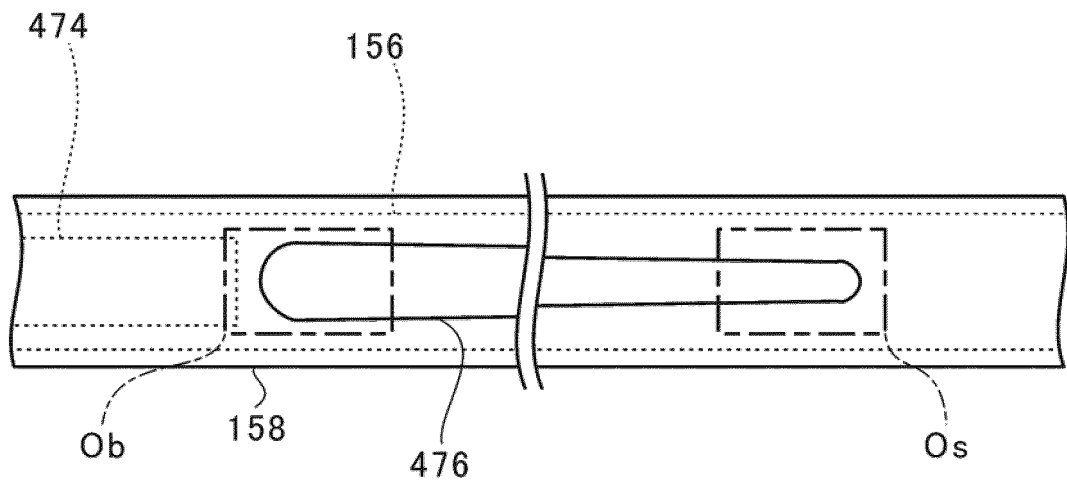


FIG. 13B

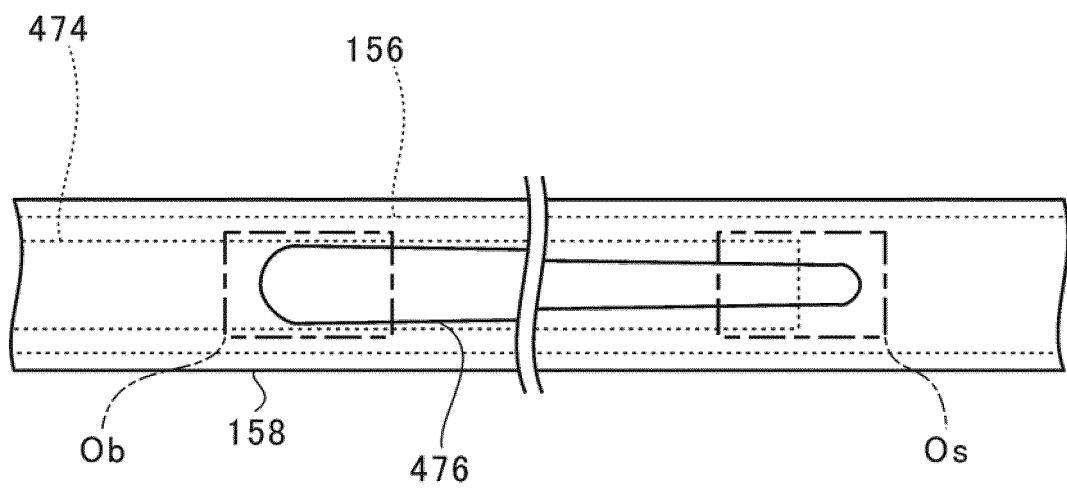


FIG. 14A

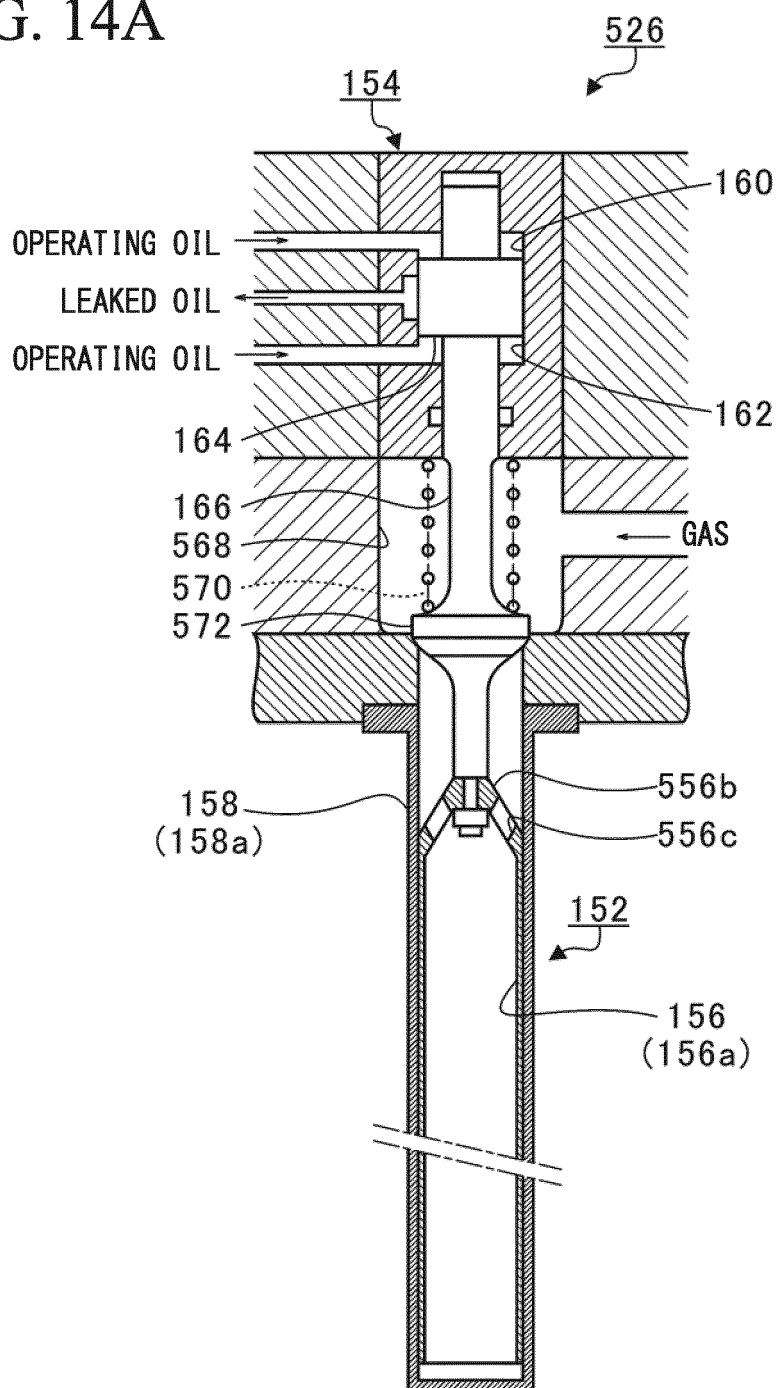


FIG. 14B

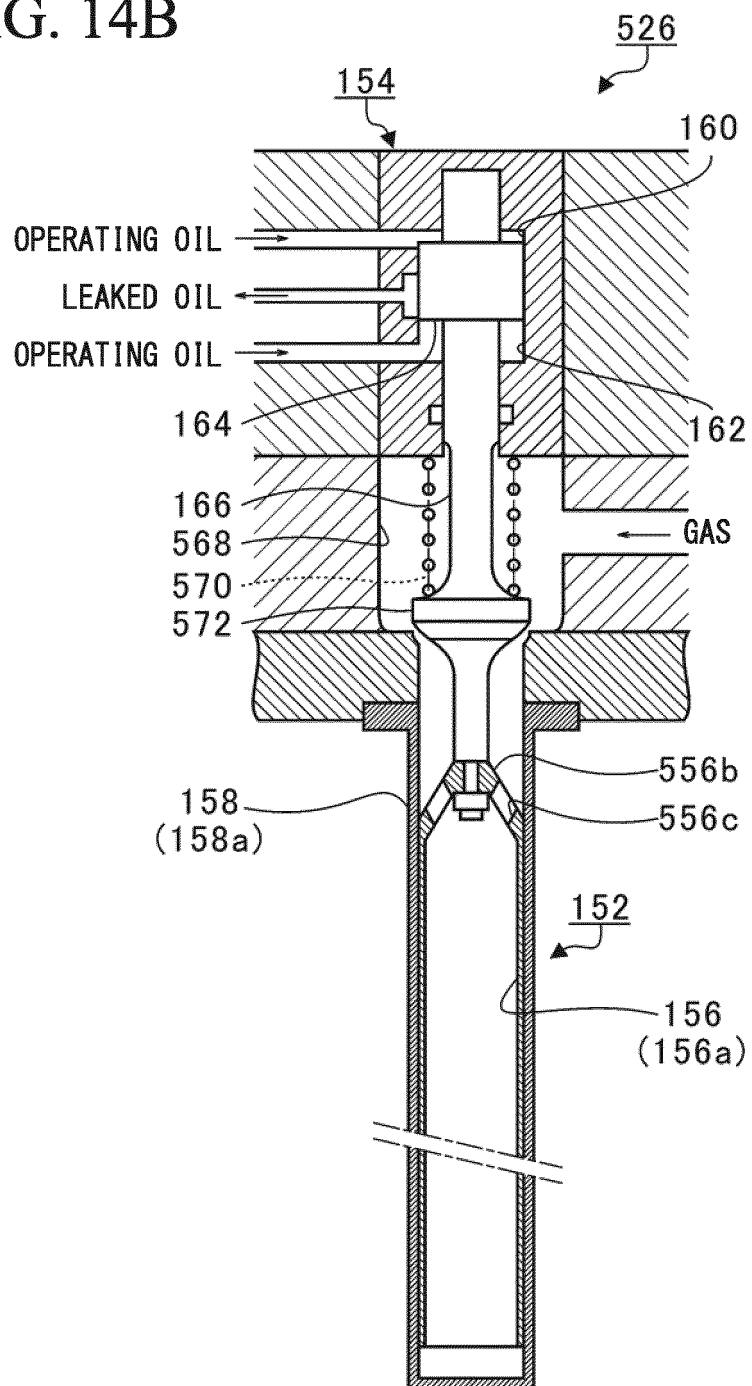


FIG. 15A

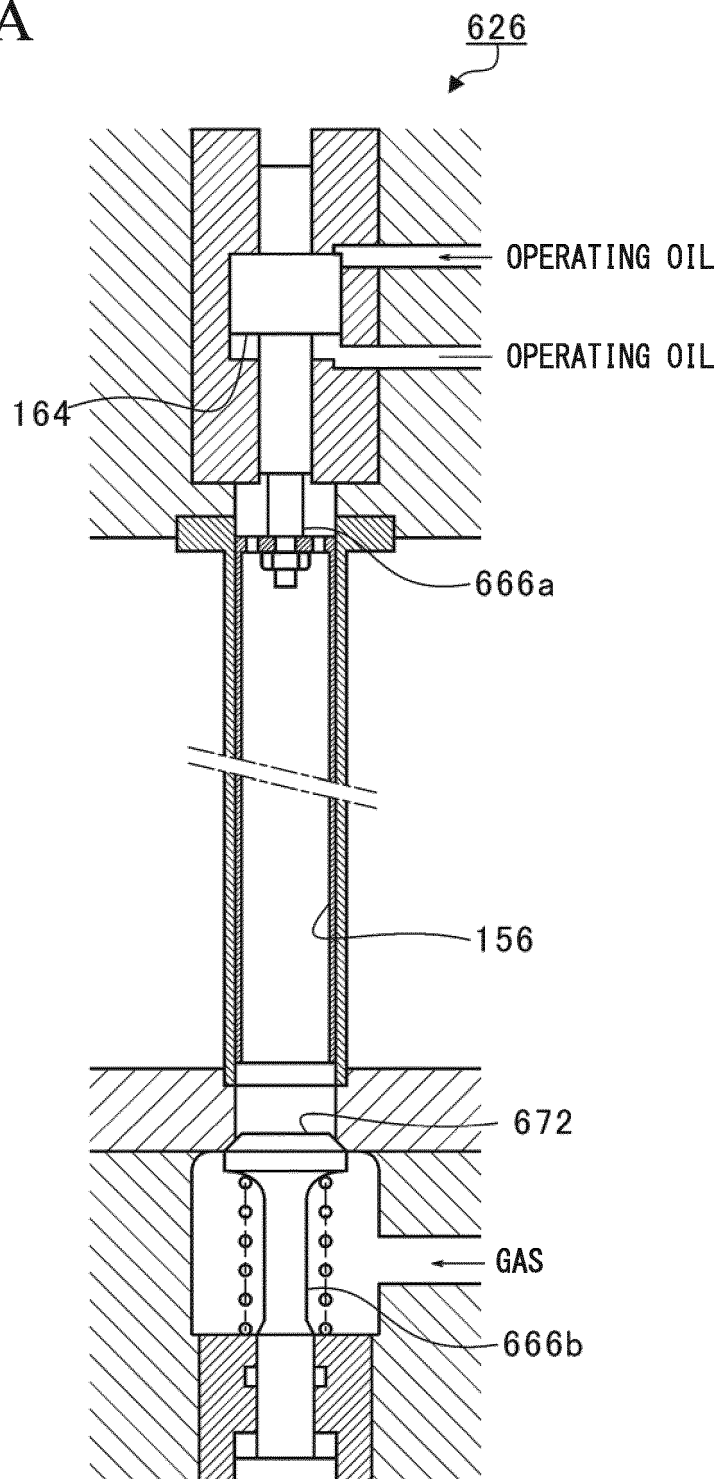


FIG. 15B

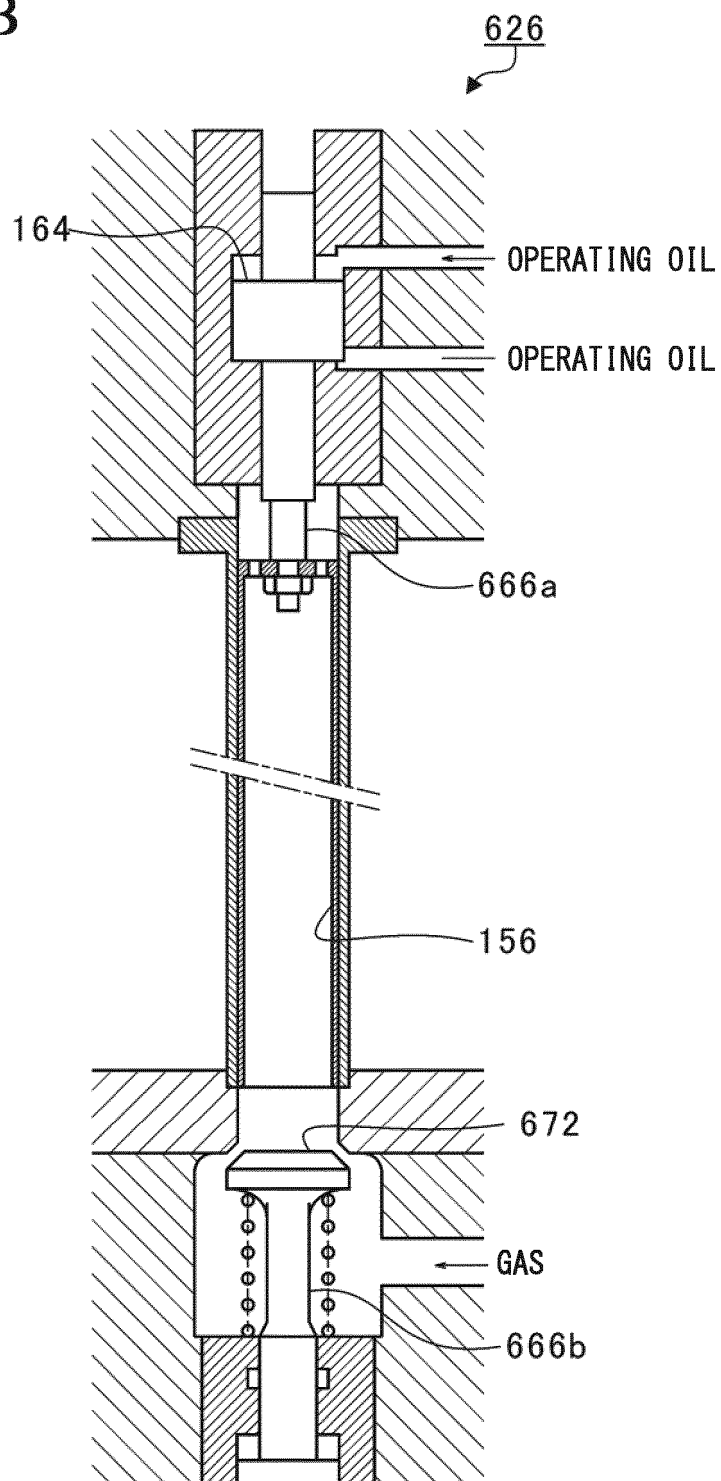


FIG. 16A

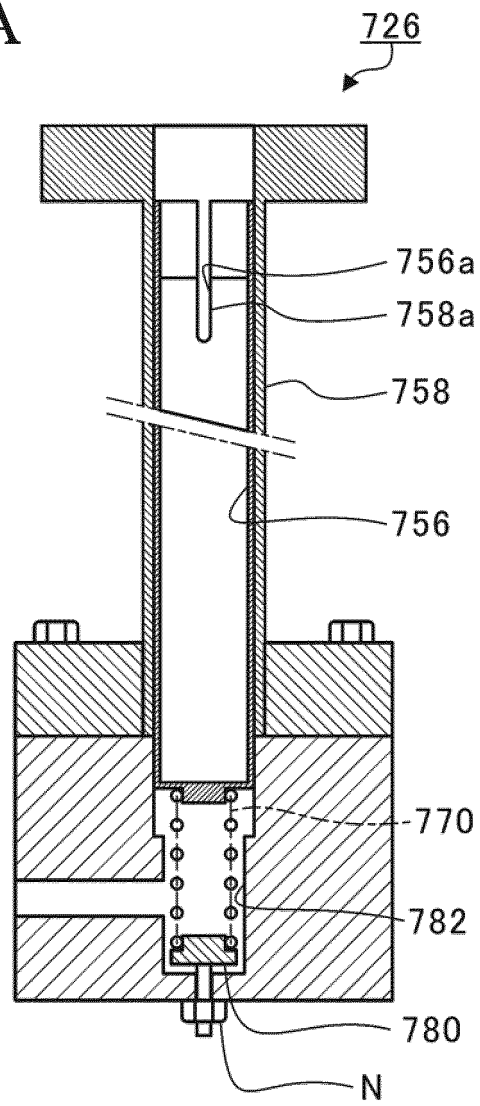


FIG. 16B

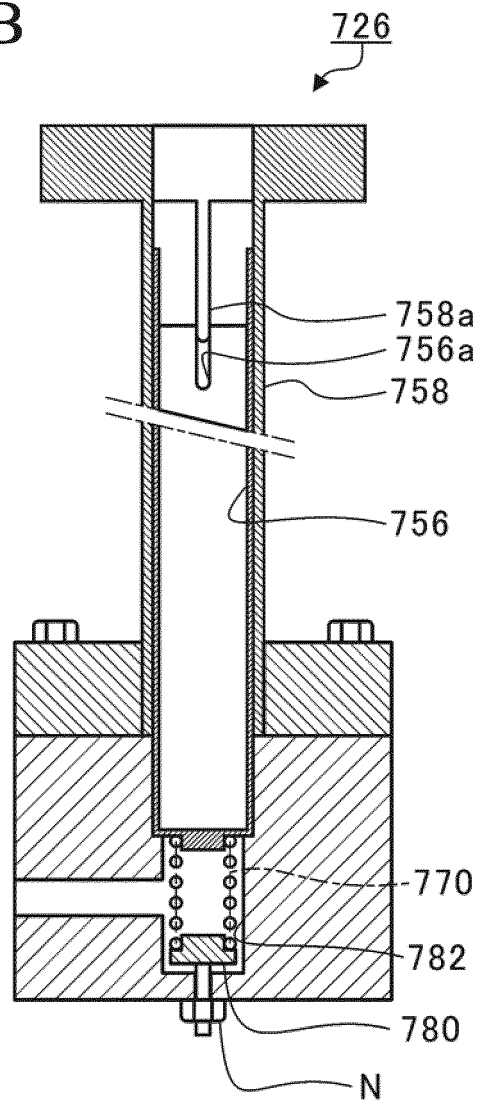


FIG. 17

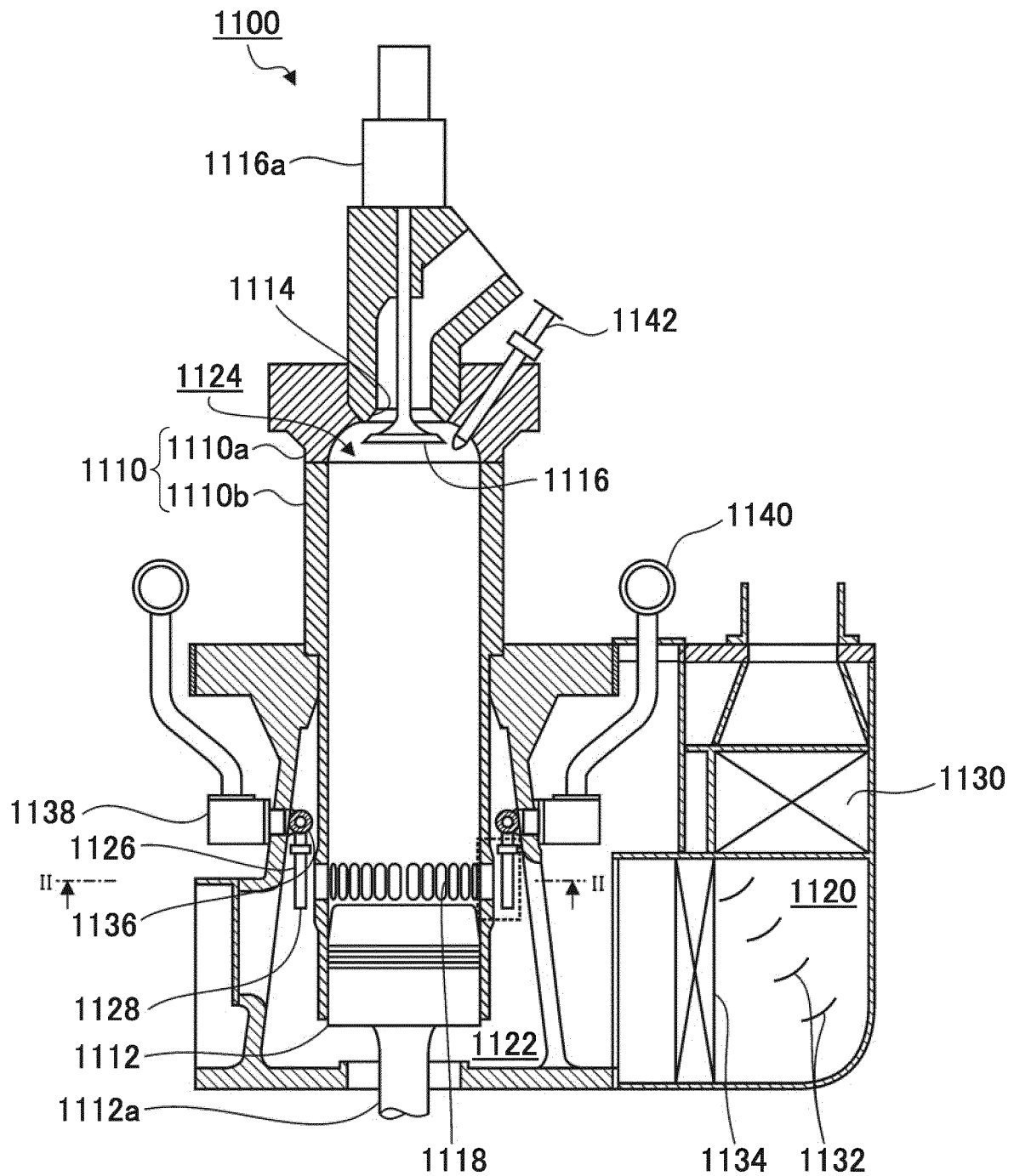


FIG. 18

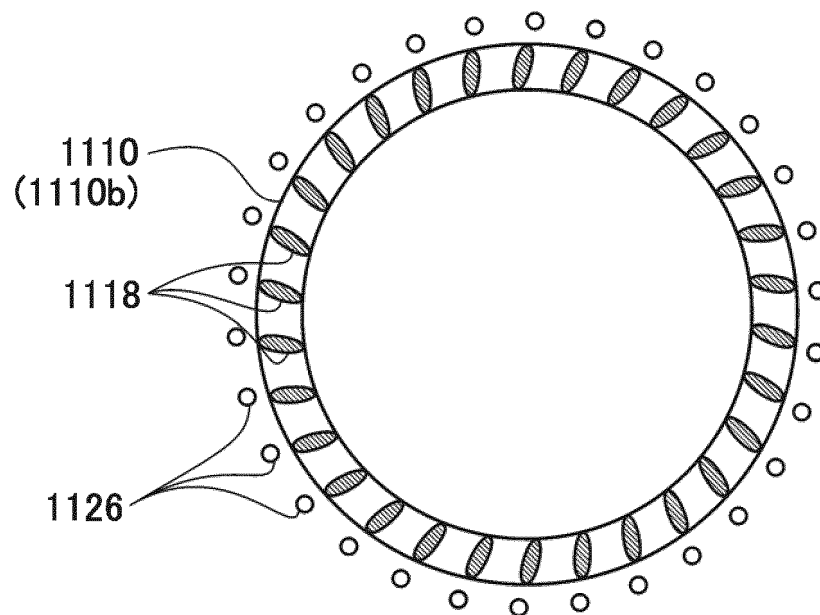


FIG. 19

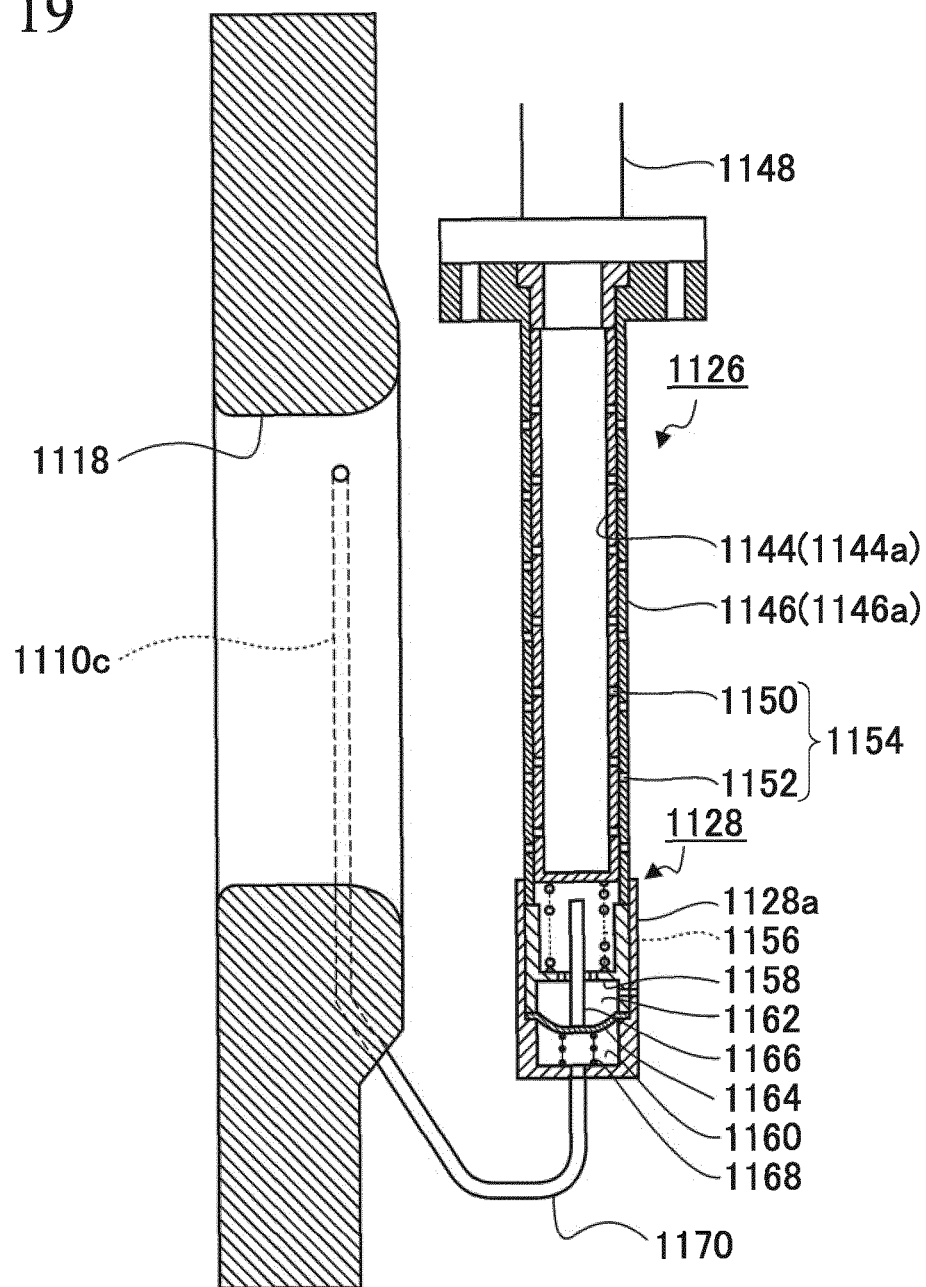


FIG. 20

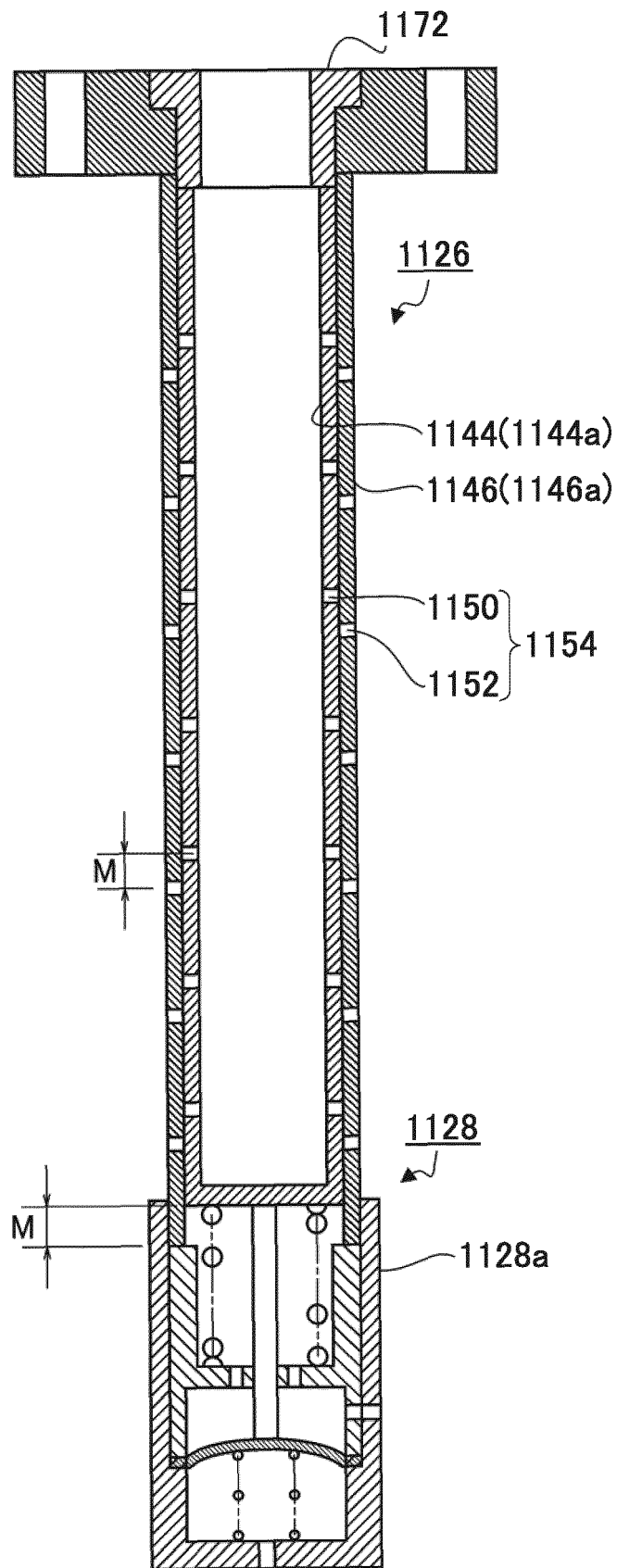
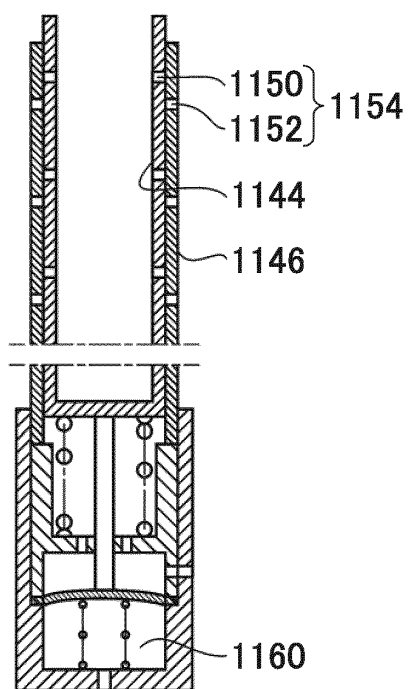
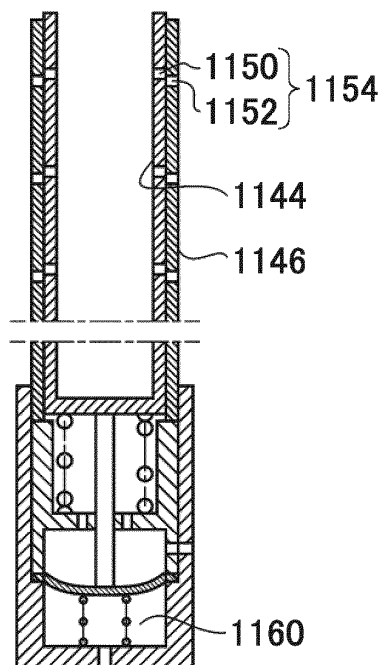


FIG. 21A



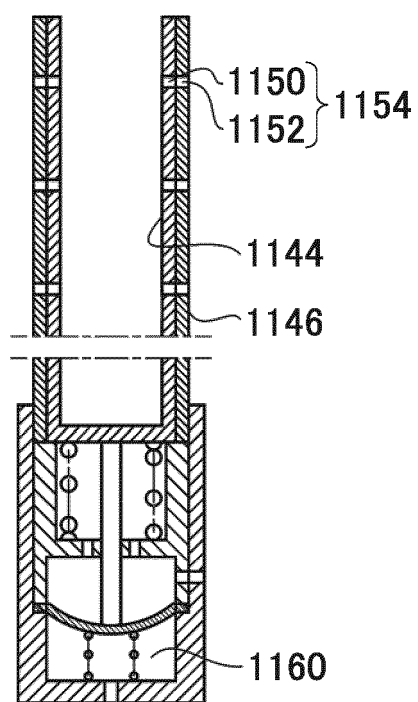
FUEL INJECTION
OPENING
FULL CLOSE

FIG. 21B



FUEL INJECTION
OPENING
CHOKE

FIG. 21C



FUEL INJECTION
OPENING
FULL OPEN

FIG. 22A

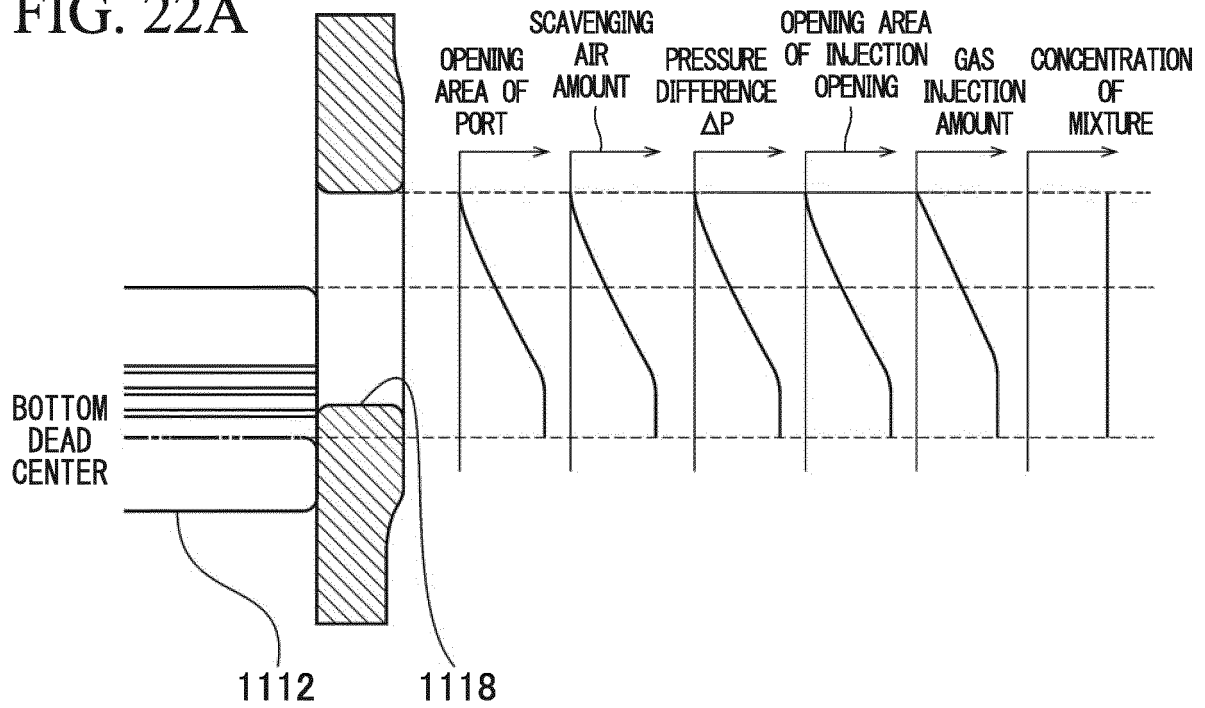
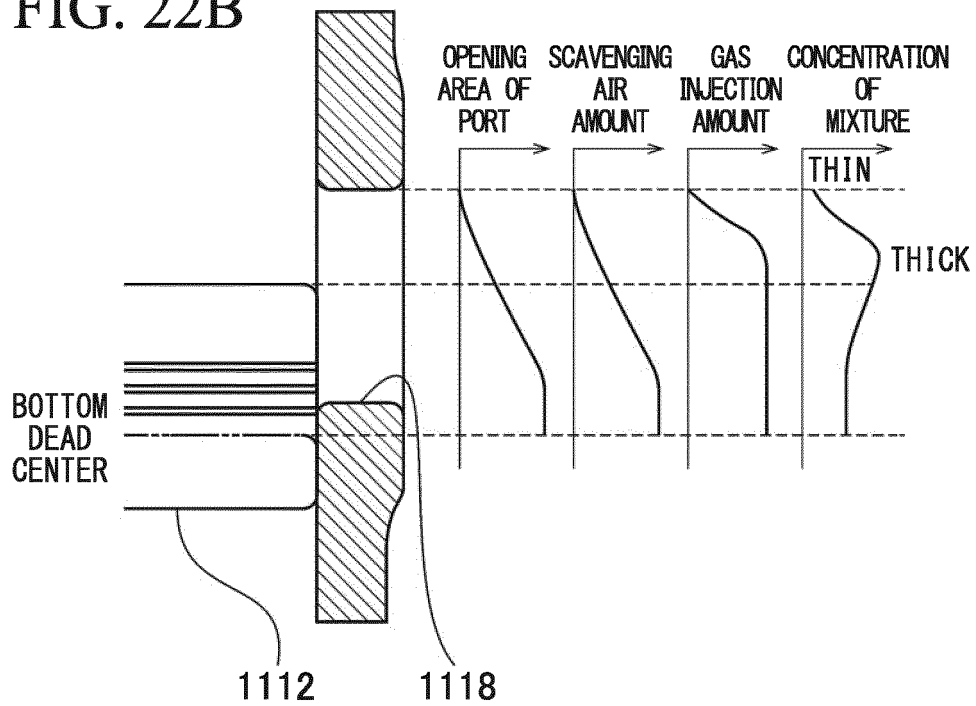


FIG. 22B



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/080894

A. CLASSIFICATION OF SUBJECT MATTER

F02M69/54(2006.01)i, F02B25/04(2006.01)i, F02M21/02(2006.01)i, F02M69/10(2006.01)i, F02M69/52(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F02M69/54, F02B25/04, F02M21/02, F02M69/10, F02M69/52

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2015
Kokai Jitsuyo Shinan Koho 1971-2015 Toroku Jitsuyo Shinan Koho 1994-2015

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2014-118858 A (Kawasaki Heavy Industries, Ltd.), 30 June 2014 (30.06.2014), paragraphs [0042] to [0043]; fig. 7 & WO 2014/091763 A & CN 104838126 A & KR 10-2015-0089088 A	1 2-9
Y A	JP 2005-163683 A (Mitsubishi Heavy Industries, Ltd.), 23 June 2005 (23.06.2005), paragraphs [0013] to [0019]; fig. 1 to 3 (Family: none)	1 2-9

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

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

"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

"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

"&" document member of the same patent family

Date of the actual completion of the international search
25 December 2015 (25.12.15)

Date of mailing of the international search report
12 January 2016 (12.01.16)

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

International application No.

PCT/JP2015/080894

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2014-47707 A (IHI Corp.), 17 March 2014 (17.03.2014), & US 2015/0167537 A1 & WO 2014/034847 A1 & EP 2891780 A1 & KR 10-2015-0044956 A & CN 104583557 A	1-9
P, A	WO 2014/181864 A1 (IHI Corp.), 13 November 2014 (13.11.2014), & KR 10-2015-0119296 A	1-9

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2014224455 A [0002]
- JP 2014224456 A [0002]
- JP 3908855 B [0005]