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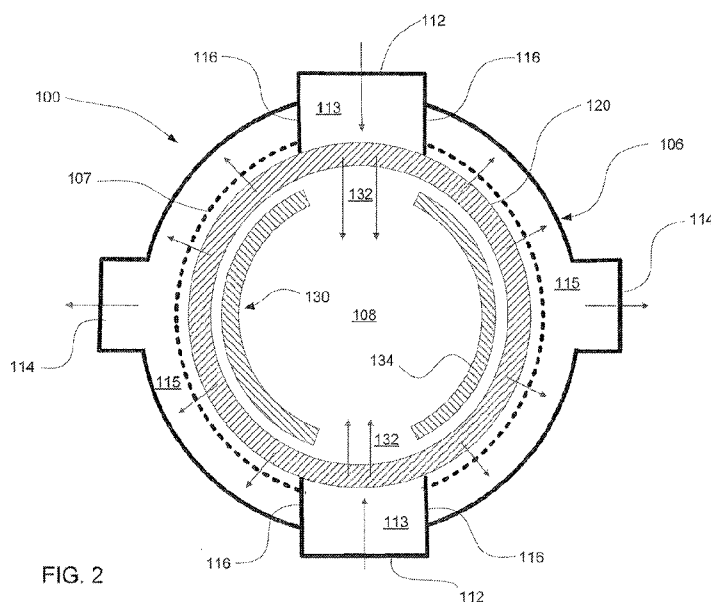
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- as to applicant's entitlement to apply for and be granted a
patent (Rule 4.17(ii))
- of inventorship (Rule 4.17(iv))

[Continued on next page]

(54) Title: NITROGEN EXTRACTOR



(57) Abstract: A device for extracting Ni-
trogen from ambient air includes a cyl-
indrical housing having first and second
ends and a circumferential surface interme-
diate the ends, the container having an
opening on the first end and at least one in-
let port and one outlet port formed on the
circumferential surface, and a Zeolite struc-
ture mounted in the cylindrical container
for rotation, wherein the at least one inlet
port is configured to receive pressurized
ambient air and to direct the received air to
a portion of the Zeolite structure aligned
with the at least one inlet port and the at
least one outlet port is configured to
provide suction to portions of the Zeolite
structure aligned with the at least one outlet
port for removing Nitrogen adsorbed by the
Zeolite structure. Air with enriched Oxygen
content is collected in a cavity defined by
the Zeolite structure and may be removed
from the device through the opening on the
first end.



Published:

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NITROGEN EXTRACTOR

FIELD OF THE INVENTION

[0001] The invention relates to an apparatus to increase the oxygen content of combustion air for internal combustion engines and more particularly, to apparatus and methods for separating Nitrogen from air for engine combustion.

BACKGROUND

[0002] Internal combustion engines combine air and fuel for combustion. Ambient air is about 78% Nitrogen (as N_2) and 21% Oxygen (as O_2). The remaining 1% includes other gases such as Argon (Ar), Carbon Dioxide (CO_2), Helium (He) and Methane (CH_4).

[0003] As is known, in combustion of a fuel, Oxygen is a necessary constituent and Nitrogen can form unwanted products. Increasing the Oxygen content and reducing the Nitrogen content of combustion air can have advantages, including reduced NOx emissions. Systems for separating Oxygen from Nitrogen in air are known. Such technologies include Pressure Swing Adsorption (PSA) technology and Vacuum Swing Adsorption (VSA) technology.

[0004] PSA can separate a gas from a mixture of gases using high (or increased) pressure to force ambient air through an adsorbent material body, such as zeolite. Zeolite is a member of the family of hydrated alumino-silicate minerals that has the ability to, among other things, adsorb or attract Nitrogen from air. The zeolite forms a molecular sieve that traps or attracts Nitrogen from air under pressure, but allows Oxygen to flow through. When the pressure is reduced, the trapped gas is desorbed. Desorption can be facilitated when a vacuum is applied to the adsorbent material (VSA). A hybrid technology, VPSA, incorporates both PSA and VSA.

[0005] U.S. Patent 6,722,352 describes a PSA system and process for internal combustion engines. Two PSA beds containing adsorbent (molecular sieve) materials are each mounted in cylinders and the cylinders are connected in parallel to alternately receive a flow of air. The cylinders operate out of phase. While a flow of air under pressure is delivered to a first PSA bed to trap (or, adsorb) Nitrogen and supply enriched Oxygen to the engine, a second PSA bed in the other cylinder is subject to reduced pressure to desorb (previously adsorbed) Nitrogen. This process is repeated by alternately adsorbing and desorbing Nitrogen in the two PSA beds. The '352 patent states that a high grade apparatus can produce 80% to 98% Oxygen by volume.

[0006] Methods and devices incorporating VPSA technology for removing higher percentages of Nitrogen are desirable.

SUMMARY

[0007] In accordance with an exemplary embodiment, a Nitrogen extraction device includes a cylindrical housing having first and second ends, the housing having an opening on the first end and at least one inlet port and at least one outlet port on a circumferential outer wall; and a Zeolite canister having a hollow interior mounted for rotation in the housing; wherein, the opening on the first end communicates with the hollow interior of the canister, the at least one inlet port is configured to direct air to a portion of the Zeolite canister communicating with the inlet port, and the at least one outlet port is configured to extract Nitrogen adsorbed by the Zeolite canister from a portion of the Zeolite canister communicating with the outlet port, wherein, rotation of the Zeolite canister exposes the Zeolite canister into and out of communication with the inlet port and into and out of communication with the outlet port.

[0008] In accordance with another exemplary embodiment, a method of extracting Nitrogen from combustion air, includes directing ambient air to an inlet chamber of a

cylindrical housing; adsorbing the Nitrogen from the received ambient air by a Zeolite canister housed within the cylindrical housing, the adsorption taking place within a portion of the Zeolite canister aligned with the inlet chamber as the ambient air passes through the Zeolite; collecting treated air remaining after the adsorption in a cavity defined by the Zeolite canister; rotating the Zeolite canister to align the portion containing the adsorbed Nitrogen with an outlet chamber of the cylindrical housing; and desorbing the Nitrogen from the Zeolite canister.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The several features, objects, and advantages of exemplary embodiments will be understood by reading this description in conjunction with the drawings. The same reference numbers in different drawings identify the same or similar elements. In the drawings:

[0010] **FIG. 1** illustrates a perspective view of a Nitrogen extraction device in accordance with exemplary embodiments;

[0011] **FIG. 2** illustrates an end sectional view of an exemplary Nitrogen extraction device of **FIG. 1**;

[0012] **FIG. 3** illustrates an exemplary Zeolite canister in a perspective view;

[0013] **FIG. 4** is a perspective view of a gate tube in accordance with exemplary embodiments;

[0014] **FIG. 5** is a schematic view of a Nitrogen extraction device having a motor to rotate the canister;

[0014] **FIG. 6** is a schematic view of a Nitrogen extraction apparatus for an internal combustion engine in accordance with exemplary embodiments;

[0015] **FIG. 7** is a schematic view of an alternative Nitrogen extraction apparatus for an internal combustion engine in accordance with exemplary embodiments; and,

[0016] FIG. 8 is a perspective view of a device showing an alternative housing arrangement.

DETAILED DESCRIPTION

[0017] In the following description, numerous specific details are given to provide a thorough understanding of embodiments. The embodiments can be practiced without one or more of the specific details, or with other methods, components, materials, etc. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the exemplary embodiments.

[0018] Reference throughout this specification to an “exemplary embodiment” or “exemplary embodiments” means that a particular feature, structure, or characteristic as described is included in at least one embodiment. Thus, the appearances of these terms and similar phrases in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. The headings provided herein are for convenience only and do not interpret the scope or meaning of the embodiments.

[0019] According to exemplary embodiments, a Nitrogen extraction device receives ambient air under pressure, adsorbs Nitrogen from the air in a Zeolite canister, and delivers a treated air stream having a reduced concentration of Nitrogen and an increased concentration of Oxygen. Under ideal conditions, all or nearly all of the Nitrogen in the ambient air is adsorbed by the Zeolite canister. The treated air stream may be advantageously supplied to an engine combustion chamber. A second treated air stream has an increased concentration of Nitrogen and may be exhausted to the atmosphere or used for another purpose. The Zeolite canister rotates so that its outer surface is exposed to the ambient air under pressure to adsorb Nitrogen then is exposed to a reduced pressure where Nitrogen is desorbed.

[0020] A Nitrogen extraction device in accordance with exemplary embodiments is described with reference to the figures. A perspective view of the extraction device is illustrated in FIG. 1. An end schematic view (looking in the direction of the oxygen outlet opening of end of **FIG. 1**) is illustrated in **FIG. 2**.

[0021] The device as illustrated includes a housing 100 of substantially cylindrical shape having a first end wall 102 and a second end wall 104 with a circumferential outer wall 106 between the first and second end walls. The housing 100 defines an interior space 108. The first end 102 includes an outlet opening 110 for permitting a first treated gas stream to flow out of the device. Second end wall 104 is a closed, gas impermeable wall. The circumferential outer wall 106 includes at least one inlet port 112 and at least one outlet port 114. As illustrated, there are two inlet ports 112 and two outlet ports 114 (only one outlet port is visible in FIG. 1).

[0022] The inlet ports 112 and the outlet ports 114 are shown as elongated slotted openings. Other openings, for example, a circular hole or a plurality of circular holes, may be used as is convenient.

[0023] Turning to Fig. 2, the housing 100 may include a perforated interior wall 107 spaced from the circumferential outer wall 106.

[0024] The housing 100 contains an air separation element, referred to here as a canister 120, supported for rotation in the interior space 108. According to one embodiment illustrated in Fig. 3, the canister 120 is a hollow, cylindrical body having a layer of Zeolite on an outer cylindrical surface 125 supported by an interior cylindrical substrate 127. The interior cylindrical substrate is air permeable. Alternatively, the cylindrical wall of the canister is formed entirely from Zeolite and the interior wall may be omitted. The canister 120 defines an internal cavity 127 (referring to Fig. 3) to receive gas that passes through the Zeolite layer 125 or wall.

[0025] Turning again to Fig. 2, the housing 100 includes inlet ports 112 that includes walls 116 defining inlet chambers 113 to receive ambient air and guide it to the canister 120. The walls 116 of the inlet chamber 113 direct the air to the surface of the canister 120 and prevent the ambient air from flowing about the circumference of the canister 120. An appropriate seal arrangement may be provided between the inlet chamber walls and the surface of the canister.

[0026] As the ambient air passes through the Zeolite structure of the canister 120, Nitrogen is adsorbed and Oxygen passes through to and collects in the interior space 108. The housing 100 also includes outlet ports 114 that with the outer wall 106 define outlet chambers 115. The outlet chambers 115 extend circumferentially between the inlet ports 112. The outlet ports 114 are connected to a vacuum source or other source for lowering the pressure in the outlet chambers 115 which allows Nitrogen trapped by the Zeolite layer of the canister 120 to desorb and be drawn out of the housing 100. As the canister 120 rotates, the portion of the canister exposed to the inlet chambers 113 for Nitrogen adsorption rotates into exposure to the outlet chambers 115 where the Nitrogen is desorbed. At the same time, the portion of the canister 120 exposed to the outlet chamber 115 from which Nitrogen is desorbed rotates into exposure to the inlet chamber 113 where ambient air is forced through and Nitrogen is adsorbed.

[0027] To prevent Oxygen from being drawn back from the interior space 108 through the canister 120 into the outlet chambers 115, a gate tube 130 is disposed on the interior of the canister 120. The gate tube 130, also shown in Fig. 4, is an air impermeable tube having two slots 132. The slots 132 are aligned with the inlet chambers 113 to allow Oxygen to pass into the interior space 108 of the housing 100 (shown in Fig. 2). The solid wall portions 134 are aligned with the outlet ports 115 to prevent Oxygen in the interior space 108 from flowing back through the canister 120. The gate tube 130 is non-rotatably mounted

in the housing 100 to maintain the slots 132 in alignment with the inlet chambers 113. The gate tube 130 is closer fitted to the canister 120 than is shown in the figure. In addition, a sealing arrangement may be provided between the edges of the gate tube slots 132 and the canister 120 to prevent air flow between the gate tube and the canister.

[0028] In addition, sealing arrangements may be provided between the adjacent ends of the housing 100 and canister 120 to prevent the flow of treated air from the canister interior space 108.

[0029] Fig. 5 illustrates schematically an apparatus for supporting and rotating the canister 120 in the housing 100. According to this embodiment, the canister 120 includes an end wall 122 and an open end 124. The canister 120 is positioned with the end wall 122 adjacent the second end 104 of the housing. The canister is supported at the open end 124 by roller bearings 126 mounted in the housing 100. A motor 130 or other motive device is coupled by a shaft 132 to the end wall, and the canister 120 may be rotated by the motor. Alternatively, the shaft may be rotated by the output shaft of an exhaust turbine using waste exhaust from the engine. A clutch and gearing mechanism may be used to control the speed of rotation of the canister 120. The rotation may be continuous or stepwise.

[0030] Alternatively, the canister 120 may be supported for rotation on a shaft by a framework connecting the canister to the shaft. According to another alternative, a ring gear may be fixed to the canister and be rotated by a pinion gear. The canister may be supported for rotation by roller bearings.

[0031] Fig. 6 shows a schematic view of an apparatus according to an embodiment of the invention for providing combustion air to an internal combustion engine. An engine 150 includes an air intake manifold 152 and an exhaust manifold 154. An exhaust gas turbine 160 is connected to an exhaust conduit 156 to receive exhaust gas to drive the turbine. A Nitrogen extractor 100 according to an embodiment of the invention includes an outlet 110

connected to an air intake conduit 158 to deliver treated air (reduced Nitrogen and increased Oxygen content) to the engine intake manifold 152. If necessary, a compressor 170 may be provided on the intake conduit 158. The output shaft 162 of the turbine 160 may be coupled to drive the compressor 170. The output shaft 162 is also coupled to drive a pump or compressor 172 which is connected to deliver ambient air to the inlet port 112 of the Nitrogen extractor 100. The compressor 172 may provide ambient air under about 2.5 bars pressure to the inlet port 112. The output shaft 162 is further coupled to drive a second pump or compressor 174 which is connected to provide the reduced pressure to the outlet chamber to release captured Nitrogen from the canister. The outlet of the second pump 174 may be directed to exhaust the Nitrogen to atmosphere 176 or some or all may be directed by line 178 to the engine intake 158 and mixed with the intake air in a manner similar to EGR (exhaust gas recirculation) to regulate combustion temperature in the engine 150. A valve 180 on line 178 may be controlled to allow the desired flow of Nitrogen to the engine intake 158.

[0032] An air drier 182 may be provided on a conduit feeding ambient air to the inlet port 112.

[0033] Fig. 7 illustrates an alternative apparatus that is similar to that of Fig. 6, but omits the pump/compressor 172 acting on the inlet port 112. According to the embodiment of Fig. 7, the pump/compressor 170 connected to outlet 110 to draw the Oxygen-enriched air from the interior 108 (see, Fig. 2) of the canister is configured to provide a sufficient vacuum on the interior to draw ambient air into the inlet port 112 and through the Zeolite structure of the canister.

[0034] The rate of desorption of Nitrogen is approximately one fifth ($1/5$) to one seventh ($1/7$) the rate of adsorption of Nitrogen. That is, it takes five to seven times longer to desorb Nitrogen from the Zeolite canister than to adsorb Nitrogen in the canister. Although not to scale in the figures, the relative sizes of the inlet chamber 113 and the outlet chamber

115 are selected so that a surface area of the canister 120 exposed to the inlet chamber 113 is about one seventh to one fifth of a surface area of the canister exposed to the outlet chamber 115. Thus, each of the inlet chambers 113 may correspond to about 30° (for a total of 60°) of rotation of the canister 120 and each outlet may correspond to approximately 150° (for a total of 300°) of rotation of the canister.

[0035] A method in accordance with exemplary embodiments may include steps of directing pressurized, dry, filtered air to inlet openings along a circumference of a cylindrical extraction device housing a Nitrogen extraction canister. The extraction canister may include a Zeolite structure to adsorb Nitrogen from the received air. The adsorption takes place within a section or portion of the extraction canister that is aligned with the inlet opening. The air passing through the Zeolite (after the adsorption of the Nitrogen) may be collected in a cavity defined by the extraction canister.

[0036] The section of the extraction canister that has adsorbed Nitrogen may then be rotated within the extraction device to expose that section to an outlet chamber. The rotation direction may be clockwise or counter clockwise. The outlet chamber is under ambient pressure or less than ambient pressure so that Nitrogen may be released or desorbed from the section of the extraction canister. If less than ambient pressure is desired, a pump or compressor may be provided to generate suction. The air in the cavity (having a higher concentration of Oxygen than ambient air) may then be provided to a combustion chamber of an engine. The engine advantageously is a compression ignition engine, and the invention may be installed on a vehicle, such as a truck, bus, automobile, marine vessel, or locomotive, and may be used in connection with a stationary power plant.

[0037] The shape of the canister may be other than a cylinder according to exemplary embodiments. The canister may have a spherical shape, for example.

[0038] In some embodiments, the shape of the outlet chamber may be non-uniform. As illustrated in **FIG. 8**, for example, the housing circumferential wall 118 defining the outlet chamber 115 may generally be of a tapered shape. The shape may be of a narrowing tapered shape in the direction of rotation to provide a pressure gradient in the direction of rotation.

[0039] Exemplary embodiments as described above increases the efficiency of an engine used in vehicles such as trucks for example. Typically, the pressurized air directed to a combustion chamber will be ambient air having a Nitrogen-to-Oxygen ratio of 78:21. By removing the Nitrogen, the more desirable Oxygen is being provided for combustion.

[0040] Other benefits derived from implementation of exemplary embodiments as described above may include, but are not limited to, higher power density, a cleaner back of truck cab, lower engine weight, simpler diagnostics and service repair, lower warranty cost and the ability to meet stricter emission standards.

[0041] Although exemplary embodiments have been disclosed, it will be apparent to those skilled in the art that various changes and modifications can be made which will achieve some of the advantages of embodiments without departing from the spirit and scope of the disclosure. Such modifications are intended to be covered by the appended claims in which the reference signs shall not be construed as limiting the scope.

[0042] Further, in the description and the appended claims the meaning of "comprising" is not to be understood as excluding other elements or steps. Further, "a" or "an" does not exclude a plurality, and a single unit may fulfill the functions of several means recited in the claims.

[0043] The above description of illustrated embodiments, including what is described in the Abstract, is not intended to be exhaustive or to limit the embodiments to the precise forms disclosed. Although specific embodiments of and examples are described herein for illustrative purposes, various equivalent modifications can be made without departing from

the spirit and scope of the disclosure, as will be recognized by those skilled in relevant art.

[0044] The various embodiments described above can be combined to provide further embodiments. Aspects of the embodiments can be modified, if necessary to employ concepts of the various patents, applications and publications to provide yet further embodiments.

[0045] These and other changes can be made to the embodiments in light of the above-detailed description. In general, in the following claims, the terms used should not be construed to limit the claims to the specific embodiments disclosed in the specification and the claims, but should be construed to include all possible embodiments along with the full scope of equivalents to which such claims are entitled. Accordingly, the claims are not limited by the disclosure.

What is claimed is:

1. A Nitrogen extraction device comprising:

a cylindrical housing having first and second ends, the housing having an opening on the first end and at least one inlet port and at least one outlet port on a circumferential outer wall; and

a canister having at least a layer of zeolite and having a hollow interior mounted for rotation in the housing;

wherein, the opening on the first end communicates with the hollow interior of the canister, the at least one inlet port is configured to direct air to a portion of the canister communicating with the inlet port, and the at least one outlet port is configured to extract Nitrogen adsorbed by the canister from a portion of the canister communicating with the outlet port, wherein, rotation of the canister exposes the canister into and out of communication with the inlet port and into and out of communication with the outlet port.
2. The device of claim 1, comprising a source of air under pressure connected to the at least one inlet port, wherein, the air under pressure directed to the portion of the canister in alignment with the at least one inlet port flows into the canister where Nitrogen is adsorbed and Oxygen passes into the hollow interior.
3. The device of claim 1, wherein the outlet port is connected to a source of reduced pressure to lower the air pressure in the outlet port to extract Nitrogen from the portion of the canister communicating with the outlet port.

4. The device of claim 1, wherein, the at least one outlet port connects to an outlet chamber defined by the housing.
5. The device of claim 4, wherein the at least one inlet port connects with an inlet chamber defined by the housing.
6. The device of claim 5, wherein the outlet chamber is larger than the inlet chamber.
7. The device of claim 6, wherein a surface area of the canister in the outlet chamber is five times a surface area of the canister in the inlet chamber.
8. The device of claim 1, comprising a cylindrical gate tube having a radius less than a radius of the canister non-rotatably disposed in the hollow interior of the canister, the gate tube having an open end at the first end of the housing and having a slot aligned with the inlet port.
9. A Nitrogen extraction apparatus for a combustion air supply for an internal combustion engine, comprising:
 - a cylindrical housing having first and second ends, the housing having an opening on the first end and at least one inlet port and at least one outlet port on a circumferential outer wall;
 - a first pump connected to deliver ambient air to the at least one inlet port;
 - a conduit connected to the opening to guide a first treated air flow from the housing;
 - a second pump connected to draw a second treated air flow from the at least one outlet port; and

a canister forming a Zeolite structure and having a hollow interior mounted for rotation in the housing;

wherein, the at least one inlet port is configured to direct ambient air to a portion of the canister communicating with the inlet port, wherein, Nitrogen is adsorbed by the canister and Oxygen passes through the canister to the hollow interior, the at least one outlet port is configured to extract Nitrogen adsorbed by the canister from a portion of the canister communicating with the outlet port in the second treated air flow, and the opening on the first end communicates with the hollow interior of the canister to guide the first treated air flow, wherein, rotation of the canister exposes the canister into and out of communication with the inlet port and into and out of communication with the outlet port.

10. A method of extracting Nitrogen from combustion air, comprising the steps of:
 - directing ambient air to an inlet chamber of a cylindrical housing;
 - adsorbing the Nitrogen from the received ambient air by a canister having at least a Zeolite layer housed within the cylindrical housing, the adsorption taking place within a portion of the canister aligned with the inlet chamber as the ambient air passes through the Zeolite layer;
 - collecting treated air remaining after the adsorption in a cavity defined by the canister;
 - rotating the canister to align the portion containing the adsorbed Nitrogen with an outlet chamber of the cylindrical housing; and
 - desorbing the Nitrogen from the canister.
11. The method of claim 10, further comprising:
 - providing the treated air in the cavity to an engine combustion chamber.

12. The method of claim 10, comprising directing the ambient air to the inlet chamber at greater than ambient pressure.

13. The method of claim 10, comprising desorbing Nitrogen from the Zeolite canister by subjecting the outlet chamber to less than ambient pressure.

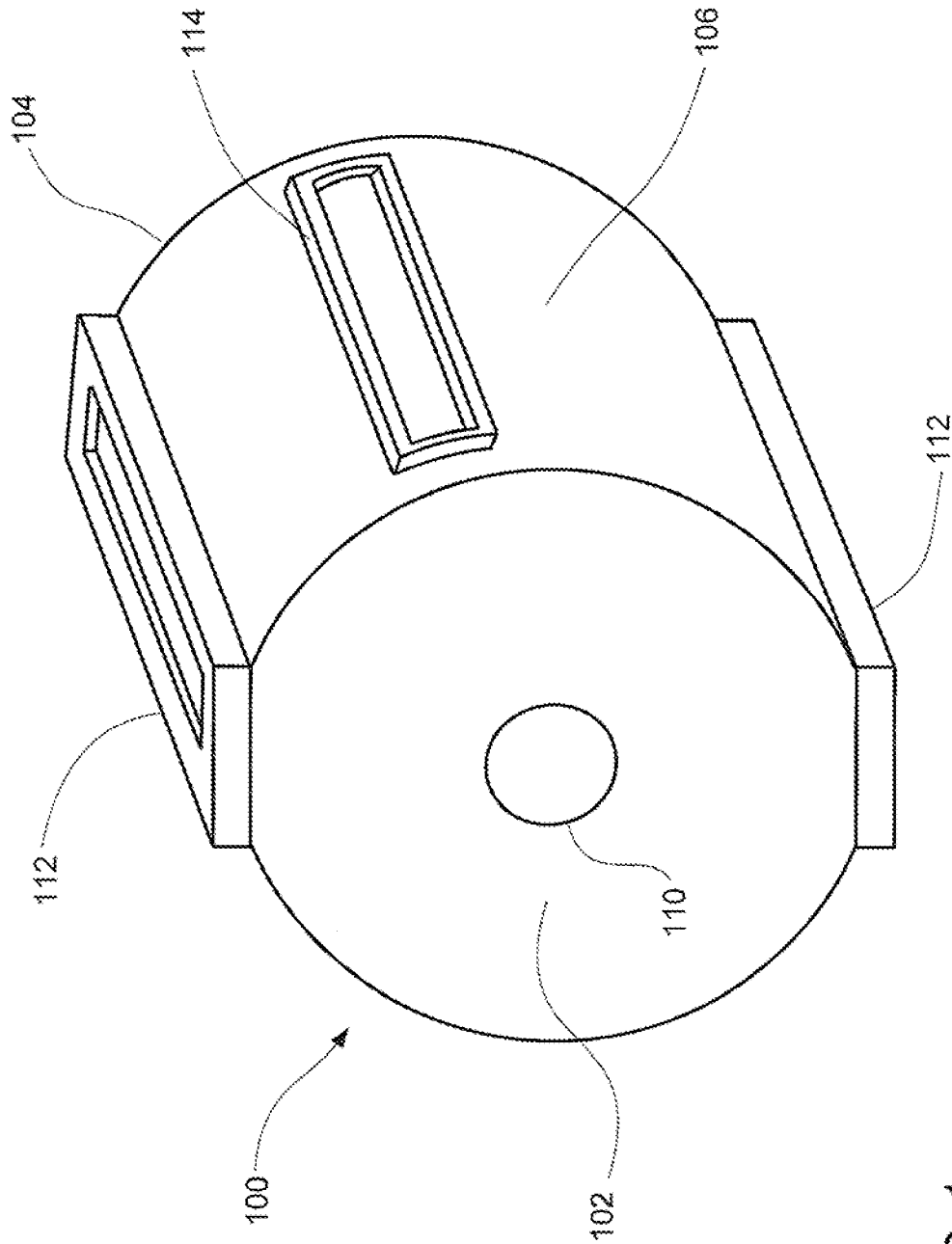


FIG. 1

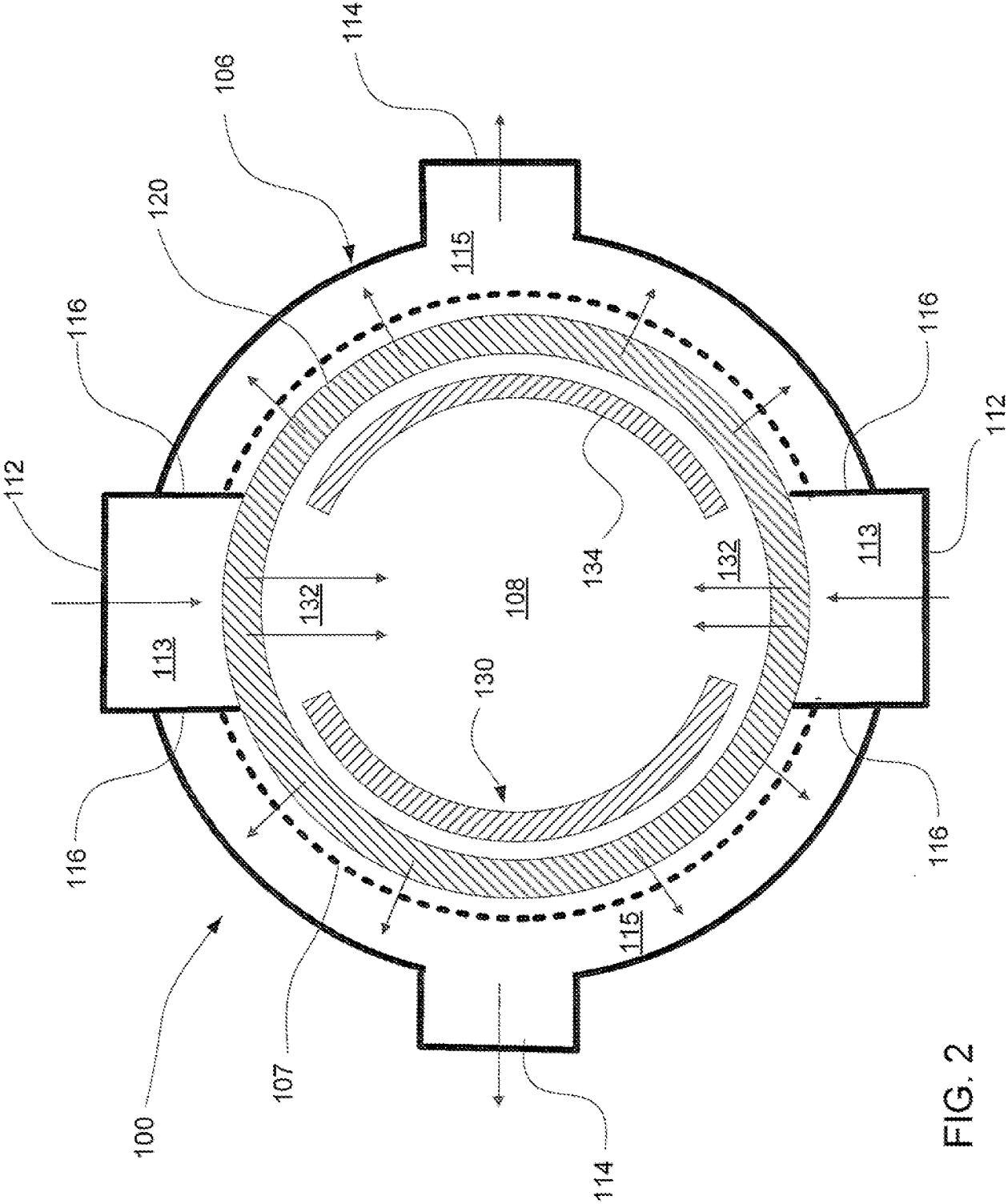


FIG. 2

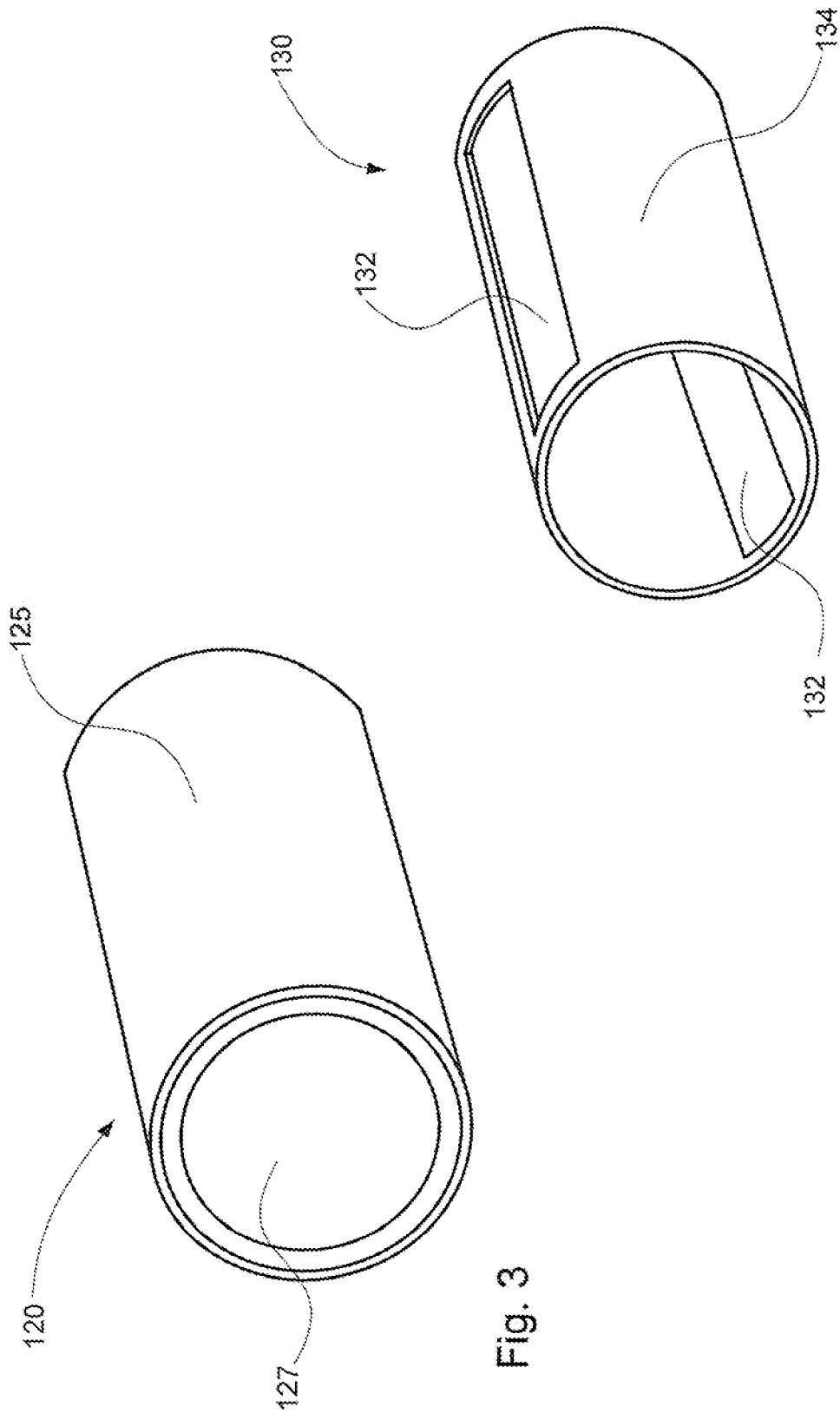


Fig. 4

Fig. 3

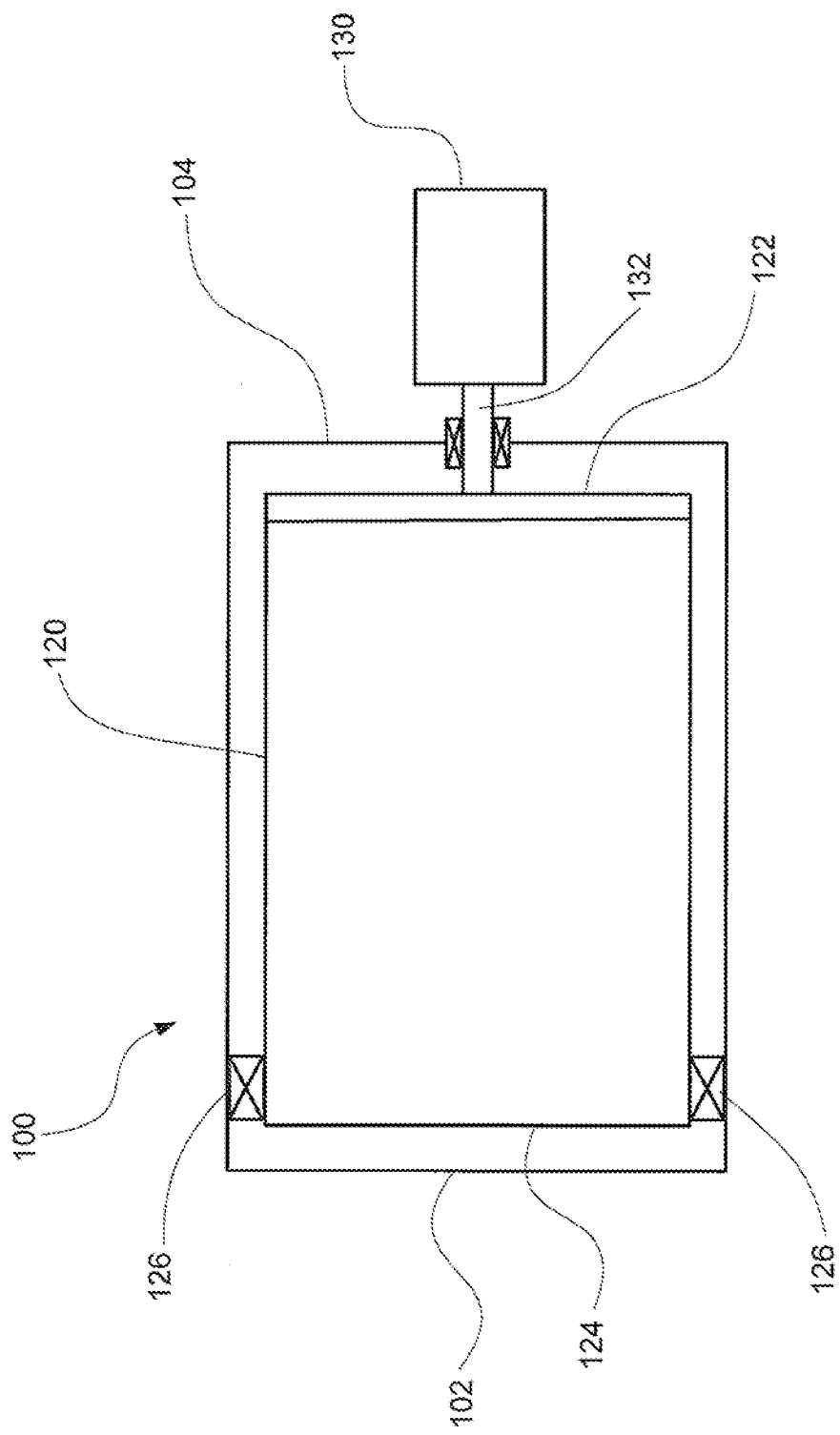


FIG. 5

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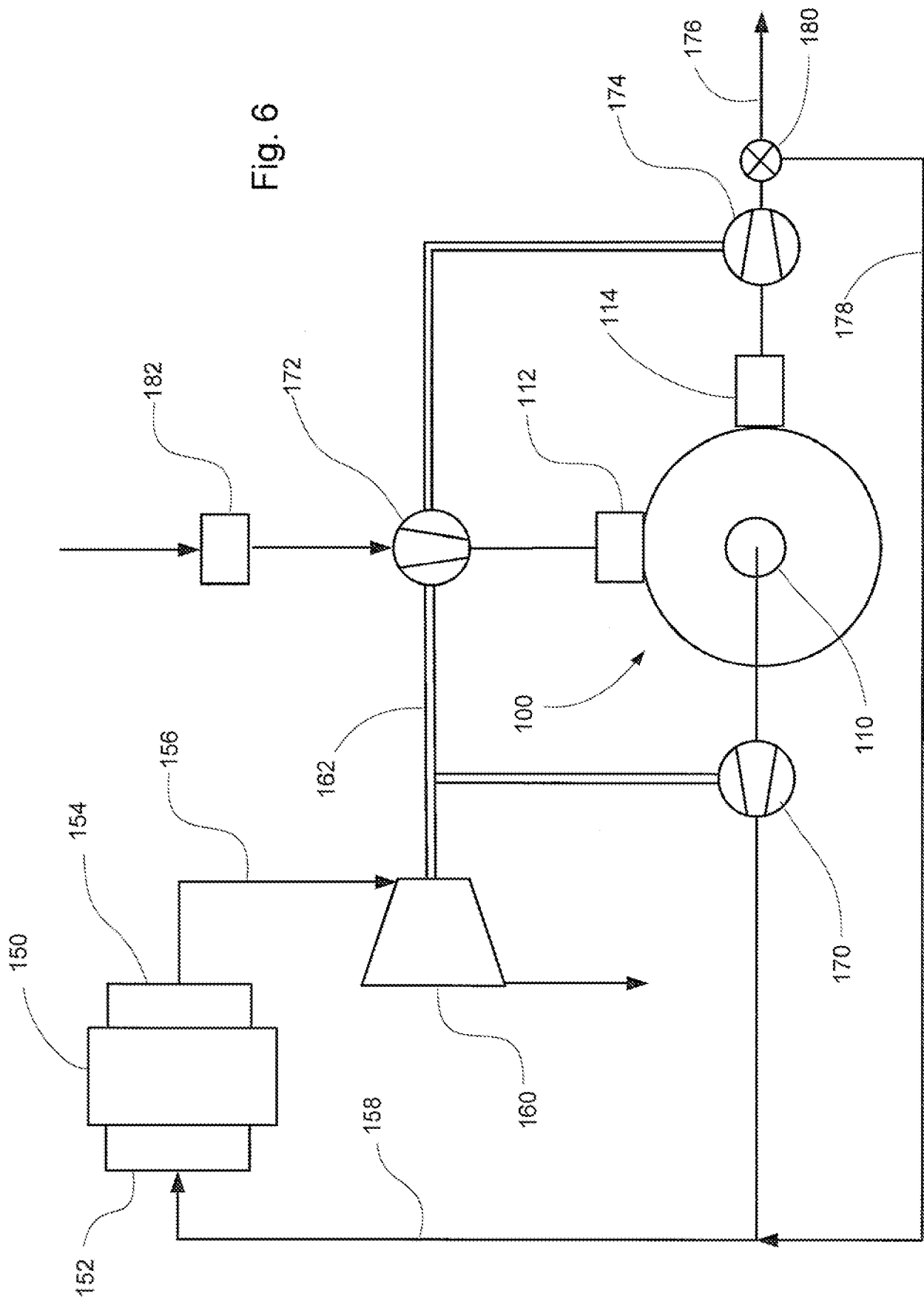
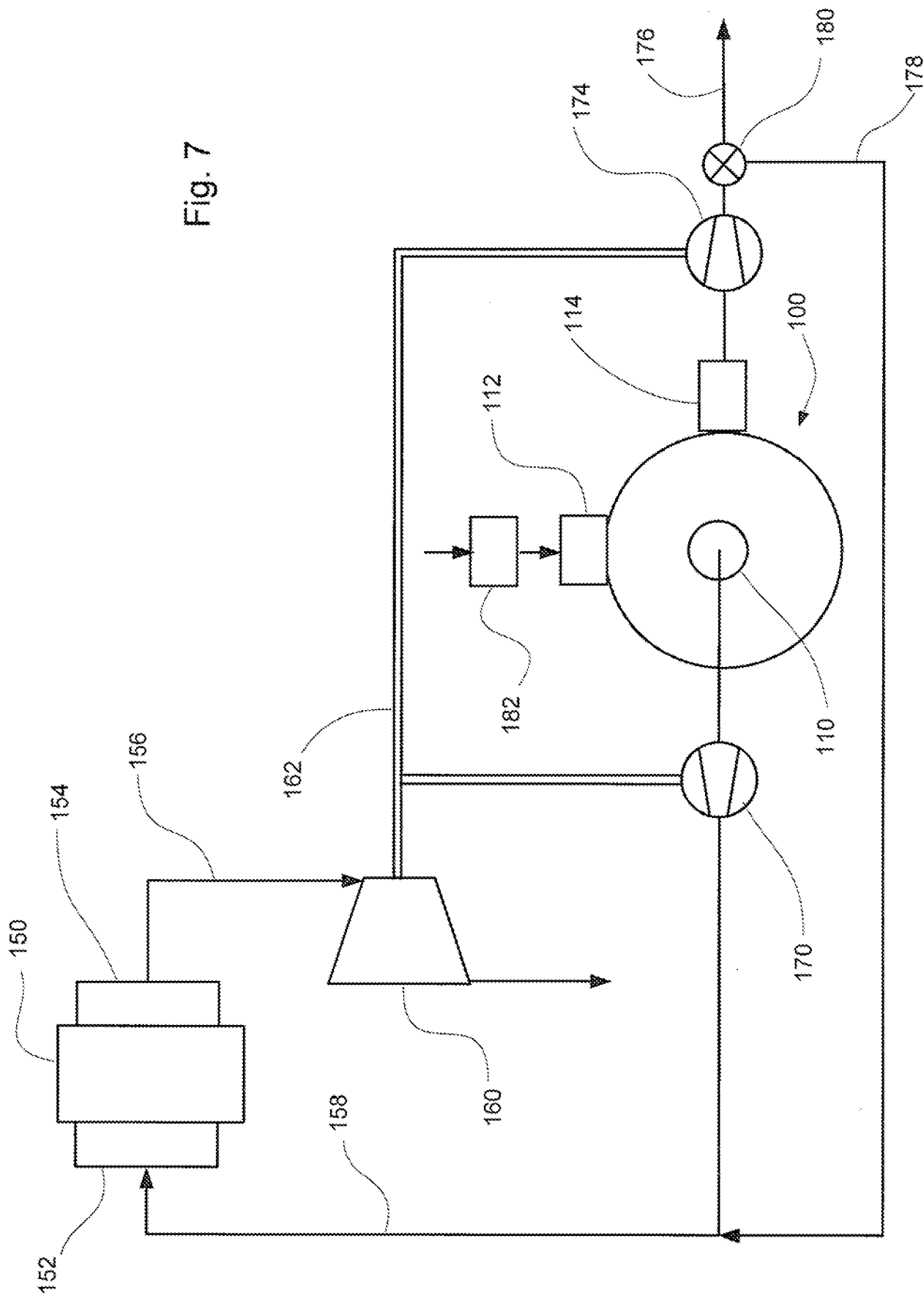


Fig. 7



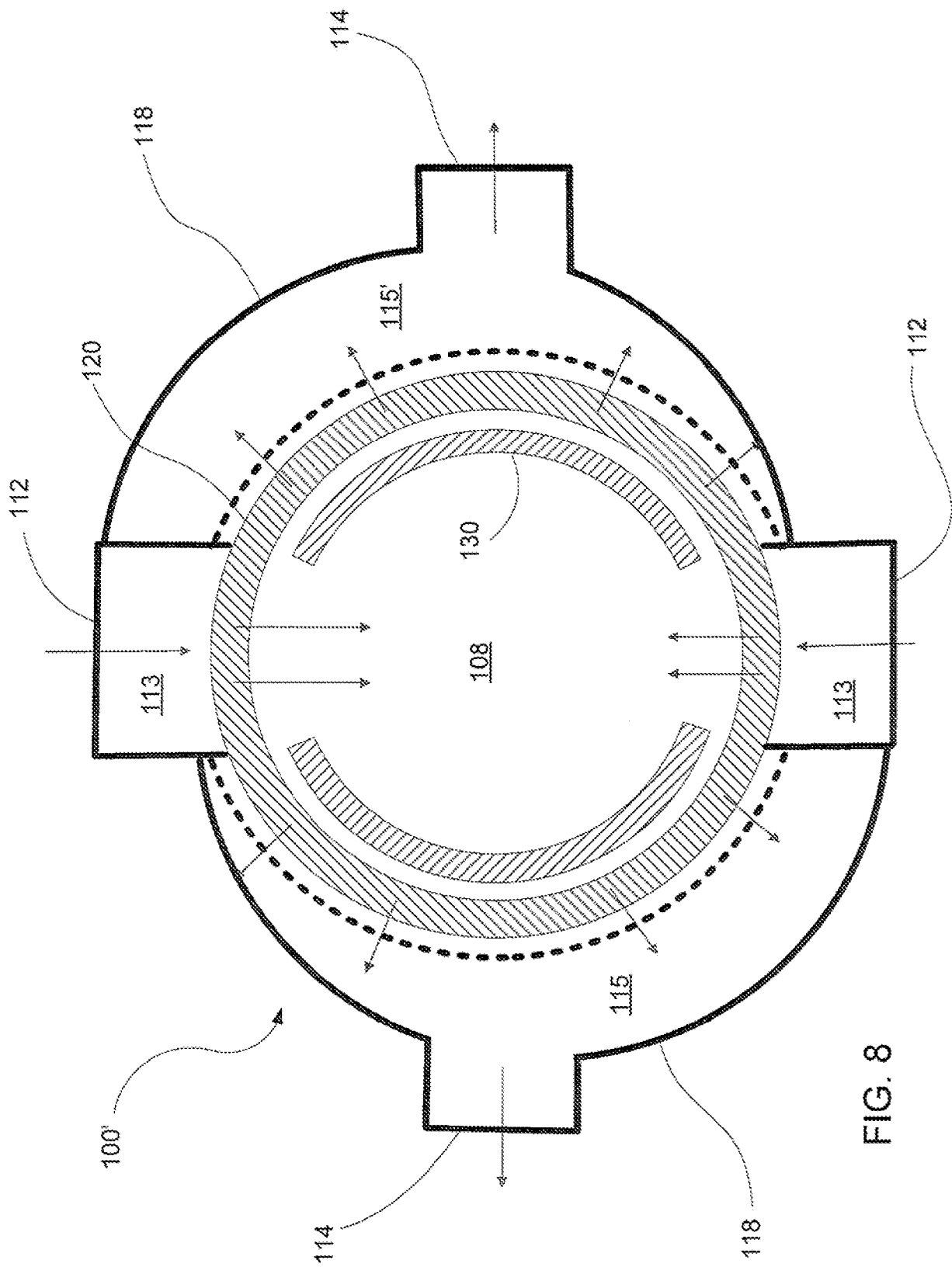


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US14/67576

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - B01D 53/06; C01B 21/04; F02M 35/02 (2015.01)

CPC - B01D 2253/108, 2257/102; C01B 21/0466

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)

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

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

PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data) Google Scholar; ProQuest; IP.com; nitrogen, zeolite, rotating, cylindrical, extractor, adsorber, inlet, large, outlet, chamber, combustion, engine, enriched, air

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X - Y	US 2002/0127442 A1 (CONNOR, DJ et al.) 12 September 2002; figures 1-3, 6, 13; paragraphs [0056], [0075]-[0076], [0093], [0110]-[0112], [0123], [0127]-[0139]	1-5 -- 6-9
X	US 3,817,232 A (NAKAJIMA, Y et al.) 18 June 1974; figures 1, 4-5; column 5, lines 41-68; column 6, lines 1-54; column 11, lines 26-68; column 12, lines 25-68; column 13, lines 1-32	10-13
Y	US 2004/0129136 A1 (HABEN, CR et al.) 08 July 2004; figures 1-3; paragraphs [0050], [0052]	6-7
Y	US 5,133,784 A (BOUDET, M et al.) 28 July 1992; figures 1, 3; column 4, lines 17-45; column 5, lines 13-31; column 7, lines 54-57	8
Y	US 2002/0104518 A1 (KEEFER, BG et al.) 08 August 2002; paragraphs [0012], [0014]	9
A	US 3,197,944 A (WESTEREN, HW et al.) 03 August 1965; entire document	1-13

☐ Further documents are listed in the continuation of Box C.

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Date of the actual completion of the international search

28 January 2015 (28.01.2015)

Date of mailing of the international search report

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Authorized officer:

Shane Thomas

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US14/67576

-----Continued from Box B. FIELDS SEARCHED

IPC(8): B01D 53/00, 53/047, 53/06, 53/55; C01B 21/00, 21/04; F02B 51/00, 75/00, 75/12; F02M 27/00, 33/00, 35/00, 35/02, 35/10 (2015.01); CPC: B01D 53/00, 53/02, 53/047, 53/06, 53/54, 2253/00, 2253/108, 2257/00, 2257/102; C01B 21/00, 21/02, 21/04 21/0405, 21/045, 21/0466; F02B 51/00; F02M 27/00, 33/00, 35/00, 35/02, 35/0201, 35/10; USPC: 55/290, 383; 95/107, 113; 96/115, 121, 125, 292; 123/26, 184, 184.47, 585, 587