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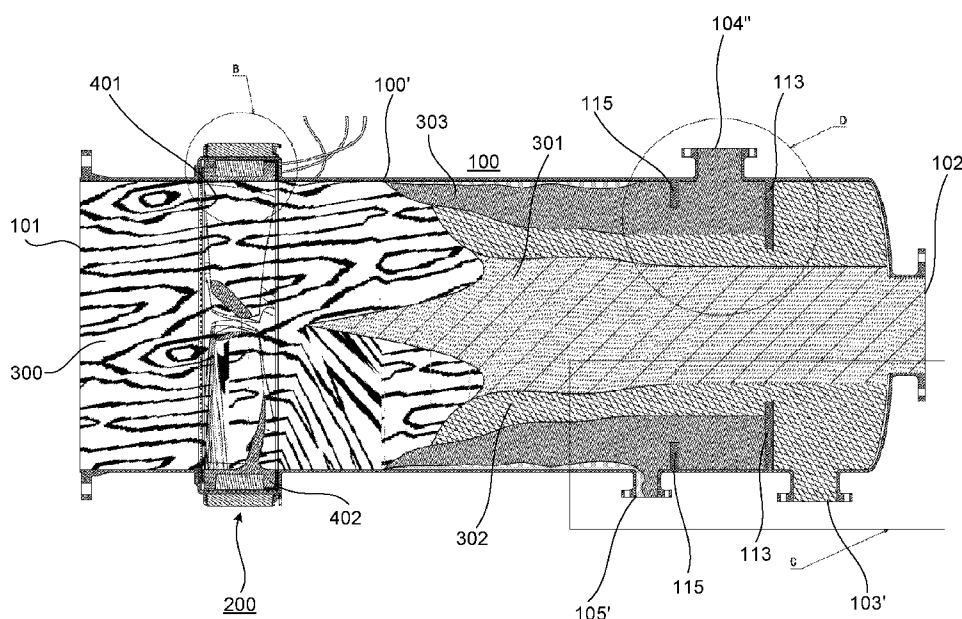


Fig. 3A

(57) Abstract: Multi-phase fluid separator (100) comprises an elongate housing (100') with a circular cross-section along its elongate axis (L). Multi-phase fluid (300) enters at inlet (101) and is set into rotation by a shaft-less spin-up device (400) which creates a highly centrifugal gravitational force that drives the heaviest liquid phases out to the wall of the separator (100) and the light phase along the longitudinal axis of the separator (100). The shaft-less permanent electromagnet motor (200) is driving vanes (401) mounted in a rotary frame (402). Contaminated heavy phase containing solids exits at outlet (105) where solids is prevented from further flow by weir (115). Non-contaminated heavy phase fluid (303) exits at outlet (104) and is prevented from further flow by weir (113). Intermediate weight phase fluid (302) exits at outlet (103), whereas the lightest fraction exits the separator (100) through a centrally arranged light phase outlet (102).

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UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
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MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
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MULTI-PHASE FLUID SEPARATOR AND THE USE OF SUCH SEPARATOR

The invention is related to a multi-phase fluid separator, as appears from the preamble of claim 1 and use thereof according to claim 10.

Background

5 Multi-phase separators in industry and oil exploitation. There are two main types of separators: horizontal and vertical. The flow in both horizontal and vertical separators is similar for two-phase separators whereby the mixture enters at the side or end of the vessel, the lighter fluid (usually gas) passes out at the top, and the heavier fluid is withdrawn at the bottom.

10 In a three-phase separator, the fluid is entering at one end of the vessel and the liquids being allowed to settle out at one side of the vessel. The oil layer floats on top of the water layer and spills over a weir into an oil chamber, where it is withdrawn under level control. The water layer remains on one side of the weir and is withdrawn under separate level control.

Problems can, and do, arise with the interface level control between the oil and water layers usually due to an emulsion of oil and water at the interface. This type of problem can normally be overcome
15 by using demulsifying agents, chemicals that break down emulsions, in order to give cleaner separation of the fluids.

However, prior art separators relying upon gravitational separation are voluminous and requires large space to provide the desired separation efficiency. Particularly on offshore locations, the separators also requires substantial supporting structures.

20 WO 2016/074950 describes a modularized hydrocarbon fluid process line, including a separator comprising a stationary casing 23 provided with electromagnets and stator coils 11. A rotor 22 provided with permanent magnets 6 is arranged within the stationary casing 23. A power and flow module 1 is arranged at the downstream end of the stationary casing 23 and is provided with a gas outlet 17 at the center and a peripheral outlet 13 for the heavier phase. The separator is restricted
25 to separation of two phases only. In order to provide separation of additional phases, two or more separators must be coupled in series in the fluid process line. The embodiment of Fig. 2 exhibits a cylindrical axially extending divider ring 20 which separates the flow paths of the light phase and the heavier phase. This divider ring 20 makes it difficult to obtain a proper degree of separation because the sharp flow path border provided by the divider ring 20 will cause some light phase to be entrained
30 in the heavier phase flow, and vice versa.

WO 2016/075090 describes substantially the same as WO 2016/074950, but is directed to a separator with a rotary drum 23 exhibiting an elongate screw 25, arranged on a shaft 27, which rotates the fluid to obtain separate phases within the drum. In one embodiment, the drum 23 is provided with numerous openings or slits 24 to permit transfer of a heavier fluid phase from the drum to an annular space 21 extending along and between the rotary drum 23 and a surrounding stationary casing 22.

Another example from the prior art WO 01/06090 which describes a downhole tool and method for controlling fluid flow, such as reinjecting water downhole.

Yet another example from the prior art is DE 10 2009 053660 B3 describes a gas centrifuge having a casing, and a rotor driven by a synchronous motor.

Object

An object of the present invention is to provide a multi-phase separator with smaller dimensions and less requirement for heavy supporting structures. Another object of the invention is to provide a separator of this type that allows an improved separation control. Yet another object of the invention is to provide a can be operated at high pressures without risk of leakage through prior art shaft seals.

The invention

These objects are achieved by a separator in accordance with the characterizing part of claim 1 and a use thereof according to claim 10. Additional advantageous features appear from the respective independent claims.

The invention is based on the inventive idea that multi-phase fluid can be separated in a more efficient manner by replacing gravitational based separation by increased gravity forces in the form of acceleration forces by a rotary shaft-less spin-up device in a multiphase separator.

Summary of invention

The present invention concerns a multi-phase fluid separator that exhibits an elongate housing having a first end and a second end. The housing exhibits a circular cross-section and a longitudinal axis, wherein the housing exhibits a multi-phase fluid inlet at the first end of the housing and numerous fluid outlets downstream of the first end. One or more flow-restricting means are

provided inside the housing to guide separated fluids in the housing out of respective fluid outlets, and a light phase outlet.

According to the invention, the separator further exhibits a shaft-less spin-up device arranged rotary inside the housing adjacent to the first end thereof, said shaft-less spin-up device comprising a rotary annular frame provided with numerous radially extending vanes, and numerous permanent north pole magnets distributed along the periphery of the rotary annular frame, and a south pole magnet arranged between each north pole magnet, and wherein numerous magnetic field-producing means, particularly electromagnets consisting of windings of electrically conducting wire, connected to an AC power source, are arranged along the periphery of the housing, attached to a stator frame, also denoted as static frame, located immediately radially outside the rotary annular frame with its permanent magnets.

In one embodiment, the vanes are attached to a closed axis located centrally in the housing, e.g. a center piece, serving as an anchor device for the vanes. In another embodiment, the vanes are solely attached to the rotary annular frame, leaving an aperture between the vane ends located centrally in the rotary annular frame.

Moreover, the shaft-less spin-up device can be supported by bearings where the peripheral part of the rotary frame is supported in any direction by bearings. In an alternative embodiment the bearings of the rotary frame can be lubricated by an external pump.

In yet another embodiment the separator can be provided with an insert pipe connected to the light phase outlet and extending along the longitudinal axis of the separator housing a distance upstream the separator, serving as a weir between light phase, e.g. gas phase, and heavier fluid phase, whereby the flow-restricting means inside housing closest to the light phase outlet can be omitted.

The fluid outlets from the separator can be provided in the form of one or more hollow casings, with or without weir inside the separator housing, arranged extending in the periphery of the housing adjacent to the second (outlet) end of the housing, wherein a peripheral opening is formed in at least a part of the wall of the separator housing, thus establishing flow connection between the internal of the separator housing and the internal of the peripheral casing, and wherein at least one fluid outlet is formed in the outer surface of the peripheral casing.

In order to control the rotational speed of the shaft-less spin-up device as a function of multi-phase composition and flow rate, the separator can be connected to a controller arranged to vary the frequency applied to the electromagnets.

The separator according to the present invention is particularly suitable for separating gas, oil, water and sand from subsea or underground oil-producing wells. However, the separator can also be used for separation of other fluids than multi-phase flow from oil-producing wells, wherein the heavier phase outlet can be omitted or plugged, e.g. for separation of sludge from municipal waste water plants or for separation of oil from water in oil spill. In yet another embodiment, the separator according to the present invention can be used to separate solid material floating in water, e.g. plastic items floating in fresh water or in the sea. In this case, the light-weight solid material is extracted through the light phase outlet of the separator, wherein the insert pipe in the embodiment described below can extend from the light phase outlet and close to the shaft-less spin-up device.

Definitions

The term “spin-up device” is in this context intended to refer to a device inside the fluid separator that forces the multi-phase fluid to rotate within the circular housing of the separator.

The term “shaft-less” used in connection with the term “spin-up device” defined above, is in this context intended to refer to a spin-up device arranged rotary within the separator housing without being supported by any shaft, sealed with gaskets and supported rotary within the separator housing.

The term “multi-phase” is in this context intended to refer to fluids containing multiple phases, such as fluids selected from the group consisting of gas and liquid; gas, oil and water; gas, oil, water and sand; oil and water; and water and sludge, generally solids from liquids.

Drawings

The invention is in the following described in further detail with reference to drawings, where

Fig. 1 is a side view of a three-phase separator,

Fig. 2 is a perspective view of the inlet end of the three-phase separator in Fig. 1,

Fig. 3A is a cross-section view along the longitudinal axis of the separator in Figs. 1 and 2,

Fig. 3B is a partial cross-section of part B in Fig. 3A above showing examples of shaft-less spin-up device bearings lubricated by fluid being separated,

Fig. 3C is a partial cross-section of part C in Fig. 3A above showing water/solids and oil outlets,

Fig. 3D is a partial cross-section of part D in Fig. 3A above showing a water outlet,

Fig. 4A is a perspective view of a shaft-less closed spin-up device arranged in a rotary frame with permanent magnets and bearings,

Fig. 4B is a drawing similar to Fig. 4A but with electromagnets arranged in a stationary frame,

5 Fig. 5 is a drawing similar to Fig. 3B, showing examples of supporting the shaft-less spin-up device with permanent magnets arranged in a rotary frame and externally lubricated bearings,

Fig. 6 is a drawing similar to Fig. 1 but showing a side view of a two-phase separator with an alternative outlet section and external lubrication pump,

10 Fig. 7 is a cross-section along the longitudinal axis of the separator of Fig. 6a with an insert for the light phase outlet of the separator,

Fig. 7A is a partial cross-section of the slotted outlet from the separator in Fig. 7 for the heaviest fraction, and

Fig. 8 is an end view in perspective of the inlet section of the separator showing a shaft-less spin-up device with open center.

15 Detailed description

Now with reference to Fig. 1, one embodiment of an elongate three-phase separator is shown in a side view and indicated by reference numeral 100. The separator exhibits an elongate housing 100' with a first end and second end, and with a circular cross-section and a longitudinal axis L. At the first end of housing 100', an inlet 101 is provided for the three-phase fluid to be separated. A light phase outlet 102, e.g. gas outlet, is arranged centrally at the opposite second end of the separator housing 100'. Outlets for the intermediate phase, e.g. oil, is shown at 103' and 103'' in the form of numerous pipe joints distributed along the periphery of the separator 100 adjacent to the light phase outlet 102. Further upstream of the intermediate phase outlets 103' and 103'', outlets for the heavy phase, e.g. water, is shown at 104' and 104'' in the form of numerous pipe joints distributed along the periphery of the separator 100. Further upstream of the heavy phase outlets 104' and 104'', outlets 105' and 105'' for the heaviest material, e.g. sand and water, in a manner similar to the remaining separated phases. A permanent magnet motor is shown at 200 and is powered by a power source indicated generally at reference numeral 208.

Fig. 2 illustrates the separator 100 of Fig. 1 viewed in perspective towards the inlet end 101. A shaft-less spin-up device indicated generally at reference numeral 400 is arranged rotary within the internal cavity of the separator housing 100'. The shaft-less spin-up device comprises numerous vanes 401 attached to a circular rotary frame 402.

5 Fig. 3A shows a cross-section along the longitudinal axis of the elongate housing 100' of the separator 100 during a process of separating a flow of multi-phase fluid 300 comprising for example gas, oil, water and sand. The shaft-less spin-up device 400 rotated by a permanent magnet motor 200 brings the multi-phase fluid 300 into rotation under its flow through the vanes 401 of the shaft-less spin-up device 400, whereby separation of the respective phases commences. Further
10 downstream along the longitudinal axis L of the housing 100' of the separator 100, the fluid gradually separates by centrifugal forces into a contaminated heavy phase comprising solids and water, located along the walls of the housing 100', an intermediate phase 302 comprising liquid hydrocarbons flowing closer to the longitudinal axis L of the housing 100', and into a light phase 301, e.g. gas, flowing along the longitudinal axis L of the housing 100'. Contaminated heavy phase (solids
15 and water) is extracted at outlets 105' and 105". A contaminated heavy phase weir 115 prevents solids to flow further downstream and instead leave the separator 100 through solids outlets 105' and 105". Non-contaminated heavy liquid phase 303 is extracted at heavy phase outlets 104' and 104". A heavy phase weir 113 prevents the heavy phase to flow further downstream and instead leave the separator 100 through heavy liquid phase outlets 104' and 104". The intermediate phase
20 302 flows past the heavy phase weir 113 and is extracted at intermediate phase outlets 103' and 103". The light phase 301 flowing along the longitudinal axis L of the housing 100' of the separator 100 is extracted through light phase outlet 102.

Fig. 3B shows a cut-out of the encircled section B in Fig. 3A with a schematic presentation of the permanent magnet which brings the shaft-less spin-up device 400 to rotate. In this embodiment,
25 the rotary frame 402 is provided with bearings lubricated by the multi-phase fluid. The left hand side of the drawing illustrates an axial roller bearing 406 arranged between the periphery of rotary frame 402 and separator housing 100', and a ball bearing 205 arranged between the rims of rotary frame 402 and separator housing 100'. The right hand side of the drawing illustrates an alternative embodiment, wherein a hydrodynamic bearing 203 is lubricated by the multi-phase fluid itself. The
30 circular shaft-less spin-up device 400 is at its periphery provided with a recess 402a in the rotary frame 402 which accommodates numerous permanent magnets 404/405 with north and south pole magnets attached in an alternating manner in the recess 402a. An iron core electromagnet is indicated at 202 (in the cross-section only one is shown) attached to the housing 100' of the

separator 100. In this embodiment, the shaft-less spin-up device 400 with the rotary frame 402 is not provided with any external supply of lubrication. Further details are described below with reference to Fig. 5.

Fig. 3C shows a cut-out of the encircled section C in Fig. 3A with the contaminated heavy phase (solids and water) outlet 105', contaminated heavy phase weir 115, non-contaminated heavy phase weir 113, intermediate phase outlet 103' and light phase outlet 102.

Similarly, Fig. 3D shows a cut-out of the encircled section D in Fig. 3A with the non-contaminated heavy phase outlet 104', contaminated heavy phase weir 115 and non-contaminated heavy phase weir 113. The respective phases are indicated at heavy phase 303, intermediate phase 302 and light phase 301.

In Fig. 4A, numerous south pole magnets 404 are mounted in the recess 402a in the circular rotary frame 402. Between each south pole magnet 404, a north pole magnet 405 is mounted in the recess 402a. Static frame (which advantageously constitutes a part of the separator housing) 201 is arranged enclosing the rotary shaft-less spin-up device 400 and its rotary frame 402. A roller bearing 406 allows the shaft-less spin-up device 400 to rotate with respect to the static frame 201.

In Fig. 4B, numerous stationary iron core electromagnets 202 are attached to the static frame 201 and connected to an AC power source 208. In use, the alternating current from power source 208 changes the magnetic pole of the electromagnets 202 correspondingly, i.e. the rotational speed of the shaft-less spin-up device 400 is synchronous with the frequency of the AC power source 208. Hence, the shaft-less spin-up device 400 can be brought to rotate from a parked position to a desired rpm in a controlled manner by controlling the frequency of the power source 208. The controlled power supply also enables thorough control of the fluid separator to adapt the rotational speed of the shaft-less spin-up device to varying loads and multi-phase compositions.

Moreover, in this embodiment the vanes 401 are in one end interconnected by a closed center piece 403, whereas the opposite end of the vanes 401 are attached to rotary frame 402.

Fig. 5 shows further details of an alternative embodiment of the permanent magnet motor with electromagnets 202 attached to the separator housing 100'. Rotary frame 402 is supported in bearings, here illustrated in two alternative embodiments. To the left hand side of the drawing, rotary frame 402 is supported in ball thrust bearings 205 lubricated by external lubricant supply 204, e.g. water and/or oil, from a pump 209. The peripheral part of rotary frame 402 is supported by axial roller bearings 406. An alternative bearing is shown to the right hand side of the drawing. There, a

hydrostatic bearing 203, located in a cavity, is arranged between rotary frame 402 and separator housing 100', filled with lubricant supplied with lubricant in line 204.

Fig. 6 shows a two-phase separator with an alternative arrangement of the separated phase outlets. In this embodiment, the external surface of housing 100' of the separator 100 is formed with a casing 120 at the downstream (second) end of the separator housing 100'. The casing 120 extends around the circumference of the housing 100'. An opening 121 is formed in the wall of the separator housing 100' along at least a part of the periphery of the housing 100', thus establishing flow connection between the internal of the separator and the internal of the peripheral casing 120. Numerous outlets 103 are formed in the outer surface of the peripheral casing 120. Similar to the separator shown in Figs. 1-3, a weir (not shown) is arranged immediately downstream of the peripheral casing 120. Accordingly, the weir, the peripheral casing with its peripheral opening 121, and the outlet 103 together form an outlet for the heavy phase, whereas the light phase is extracted through outlet 102.

Fig. 7 shows another embodiment of the two phase separator of Fig. 6, where an insert pipe 106 is connected to the light phase outlet 102 and extending a distance upstream inside the housing 100' of the separator 100. The insert pipe 106 assists in the separation by preventing heavy phase liquid to exit the light phase outlet 102. Accordingly, the insert pipe 106 replaces the weir embodiment. The peripheral casing 120 with outlet 103 and peripheral opening 121 are shown in further detail in Fig. 7A.

Fig. 8 shows the inlet section 101 of the separator 100 with an alternative arrangement of the vanes. Here, the closed center piece 403 is replaced by a central bore 403'. This embodiment is advantageous where the multi-phase fluid to be separated contains larger light weight objects, e.g. ropes entrained with the fluid. Here, large and various objects will flow along the center of the separator, through the central bore 403' and further downstream of the separator.

Technical effect

The present invention has several advantages compared to the prior art. Firstly, the present invention allows for more compact separator structures. For example on an installation offshore, the reduced space and weight requirement allows more equipment to be installed, or on the other hand allow use of less voluminous and heavy supporting structures than can affect (increase) the life time of existing platforms construction and reduced size of new platforms.

Moreover, the synchronous operation of the shaft-less spin-up device with permanent magnet motor enables convenient control of speed to adapt to the variations of parameters in the multi-phase flow to be separated.

5 The construction is, thanks to the axle-free arrangement of the shaft-less spin-up device, not sensitive to pressure. There are no mechanical connection between the shaft-less spin-up device 400 and the separator housing 100'. Accordingly, there are no shaft gaskets or seals that otherwise would be subject to leakage, pressure restriction and need for maintenance.

The separator can also be used for separation of other medium than multi-phase flow from oil-producing wells, e.g. sludge from municipal waste water plants. As a result, the plants are able to
10 handle flow peaks that supersede the capacity of the plant.

Moreover, the strong centrifugal field in the fluid being separated is assumed to contribute to strong coalescence of drops, including break-up of emulsions. This mechanism will effect even better separation.

Modifications

15 Whereas the present invention has been described and illustrated by a horizontal fluid separator, the present invention is applicable also to an inclined or a vertically oriented separator housing, because gravity force is negligible compared to the centrifugal forces applied to the multi-phase fluid during separation.

Moreover, the invention has been described with two- and three-phase fluids as examples of fluids.
20 However, the separator according to the invention can be adapted to numerous fluids with varying densities.

Claims

1. Multi-phase fluid separator (100) exhibits an elongate housing (100') having a first end and a second end, and with a circular cross-section and a longitudinal axis (L), wherein the housing (100') exhibits a multi-phase fluid inlet (101) at the first end of the housing (100'), numerous fluid outlets
5 downstream of the first end, a light phase outlet (102) in center, and one or more flow-restricting means (113, 115) inside the housing (100') for guiding separated fluids in the housing (100') out of respective fluid outlets, said separator exhibiting a spin-up device (400) arranged rotary inside the housing (100'), arranged to rotate by a permanent magnet motor (200) comprising numerous electromagnetic field producing means (202) connected to an AC power source (208), and numerous
10 permanent magnets (404, 405) distributed along the periphery of the rotary spin-up device (400),
characterized in that

the spin-up device (400) is shaft-less and is arranged adjacent to the first end of the housing (100'), said shaft-less spin-up device (400) comprising a rotary annular frame (402) provided with numerous radially extending vanes (401),

15 the permanent magnets comprises numerous permanent north pole magnets (405) distributed along the periphery of the rotary annular frame (402), and a south pole magnet (404) arranged between each north pole magnet (405).

2. The separator of claim 1, wherein said magnetic field producing means (202) are selected from the group consisting of electromagnets and windings of electrically conductive wires.

20 3. The separator of claim 1 or 2, wherein the vanes (401) are attached to a closed center piece (403) or a central bore (403') located centrally in the housing (101').

4. The separator of any one of claims 1 to 3, wherein the peripheral part of the rotary frame (402) is supported one or more bearings selected from the group consisting of an axial roller bearing (406), thrust bearings (205), a hydrodynamic bearing (203), a hydrostatic bearing (203) and a magnetic
25 bearing (203).

5. The separator of claim 4, wherein the thrust bearing (205) is a ball bearing.

6. The separator of claim 4, wherein said bearings (203, 205, 406) are lubricated by process fluid or filled with an external fluid lubricant supplied in line (204) by pump (209).

7. The separator of any one of the preceding claims, wherein an insert pipe (106) is connected to the light phase outlet (102) and extending along the longitudinal axis (L) of housing (100') a distance upstream the separator (100), serving as a weir between light phase (301) and heavier fluid phase (302), whereby the flow-restricting means inside housing (100') closest to the light phase outlet (102) can be omitted.
8. The separator of any one of the preceding claims, wherein said fluid outlet for the respective phases is provided in the form of a hollow peripheral casing (120) arranged extending in the periphery of the housing (100') adjacent to the second end of the housing (100'), wherein a peripheral opening (121) is formed in at least a part of the wall of the separator housing (100'), thus establishing flow connection between the internal of the separator housing (100') and the internal of the peripheral casing (120), and wherein at least one fluid outlet (103) is formed in the outer surface of the peripheral casing (120).
9. The separator of any one of the preceding claims, wherein the separator is connected to a controller arranged to vary the frequency applied to electromagnetic field producing means (202) on the static frame (201) and hence control the rotational speed (rpm) of the shaft-less spin-up device (400) as a function of multi-phase composition and flow rate.
10. Use of a separator according to any one of the claims claim 1-9 for separating sludge from municipal waste water plants and handling of oil spill onboard an oil recovery vessel.
11. The use according to claim 10 for separating solids from liquid floating in said liquid.
12. The use according to claim 11, wherein the solids is plastic items floating in fresh water or sea.

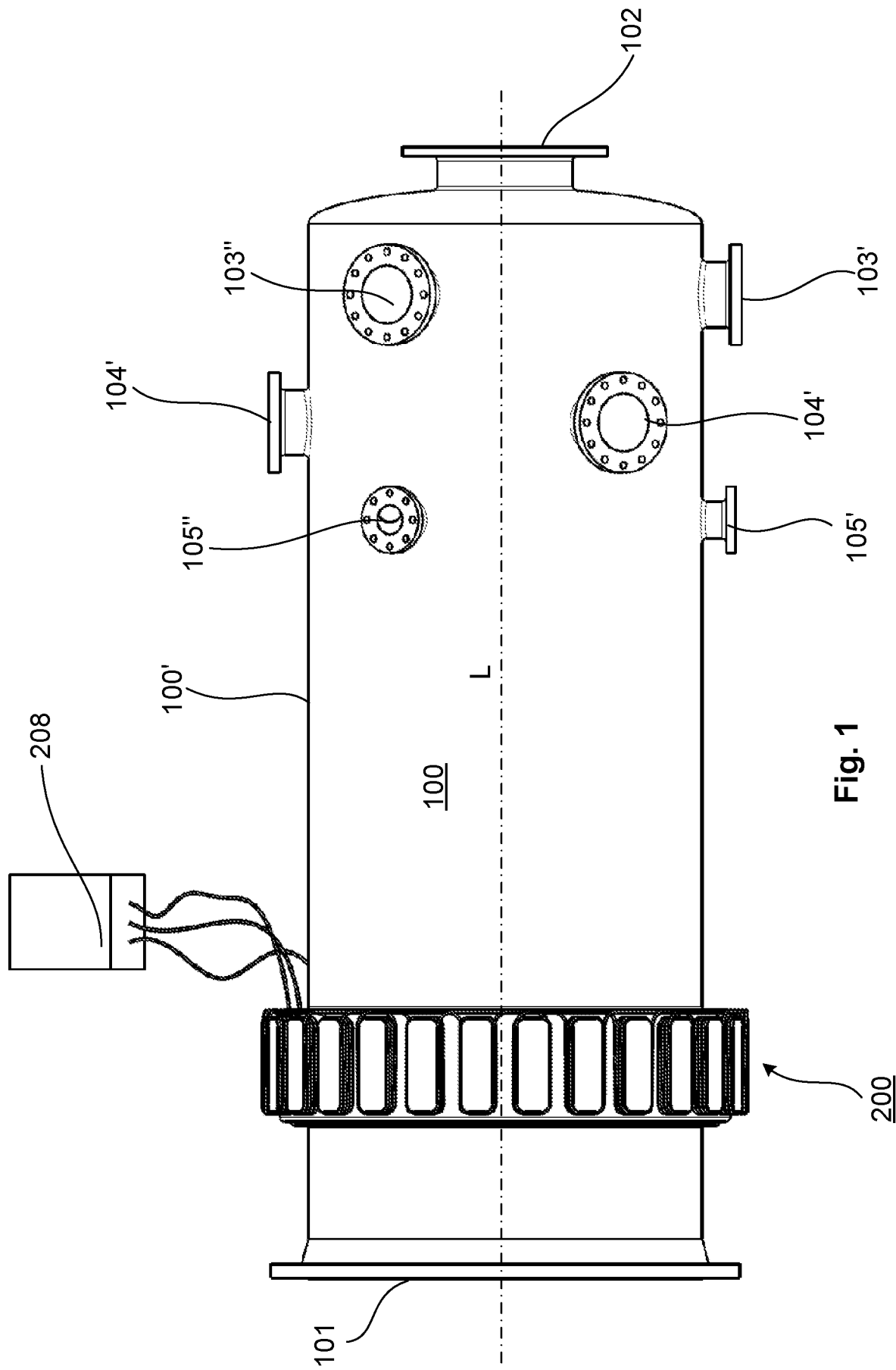


Fig. 1

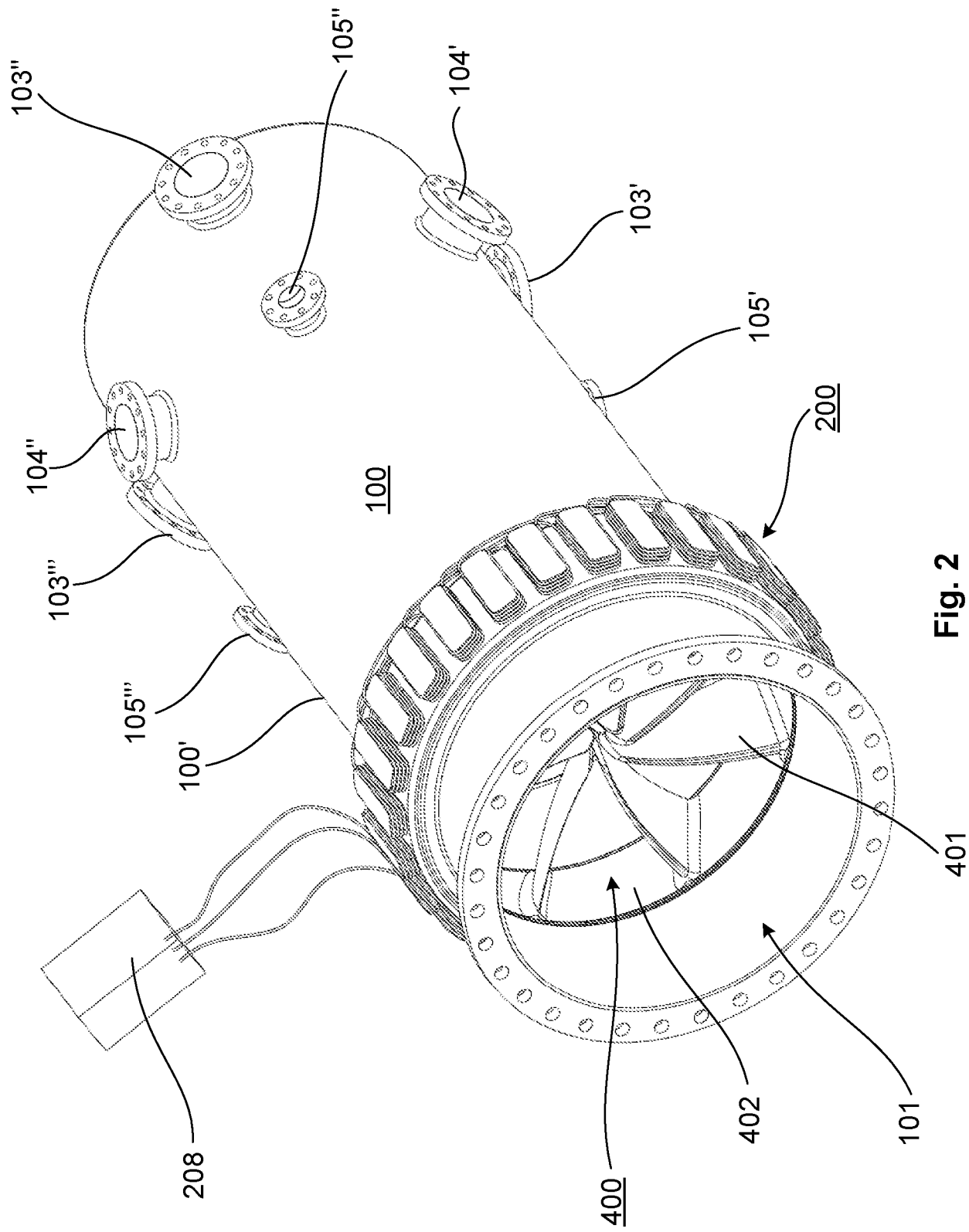


Fig. 2

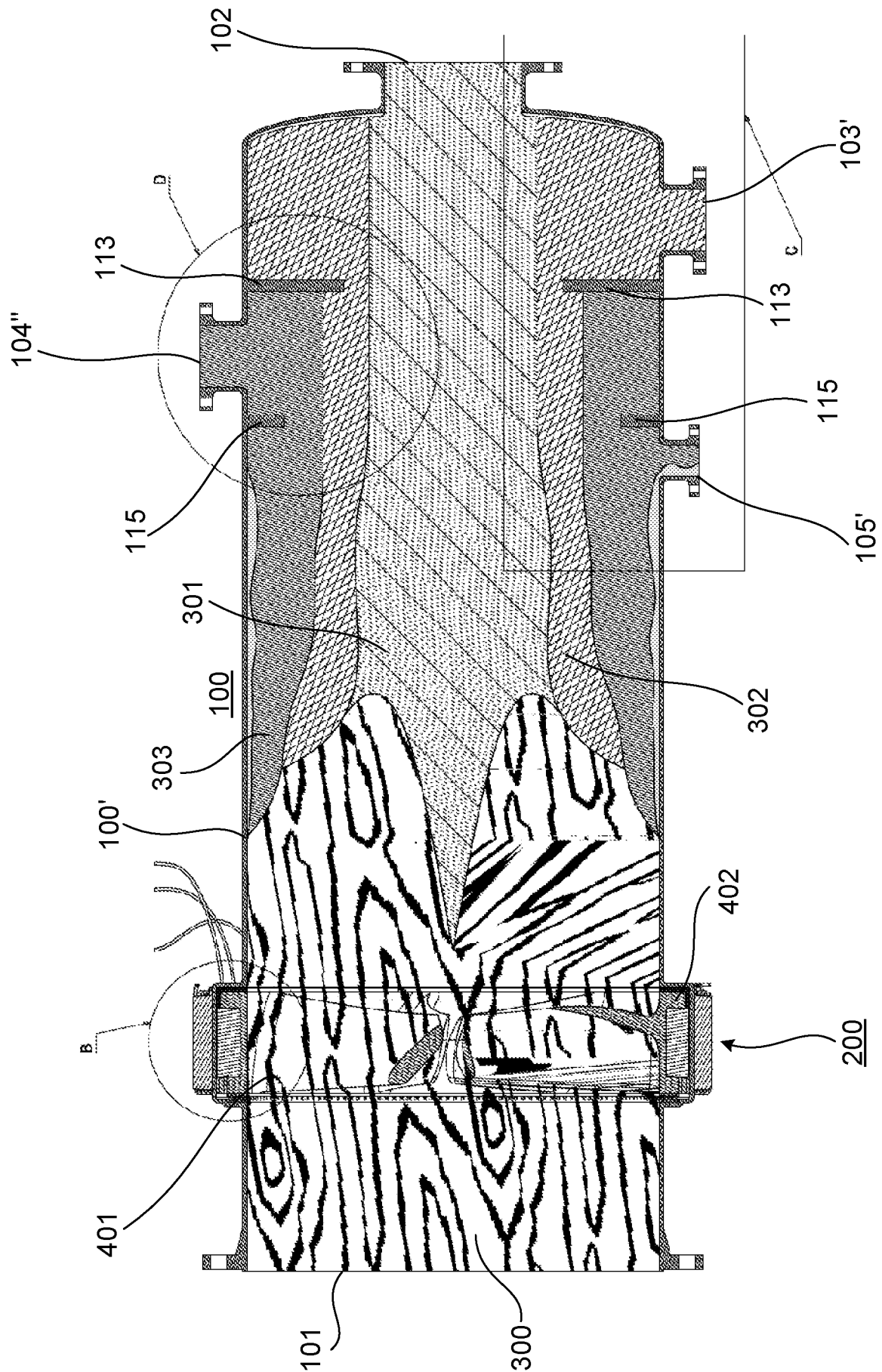


Fig. 3A

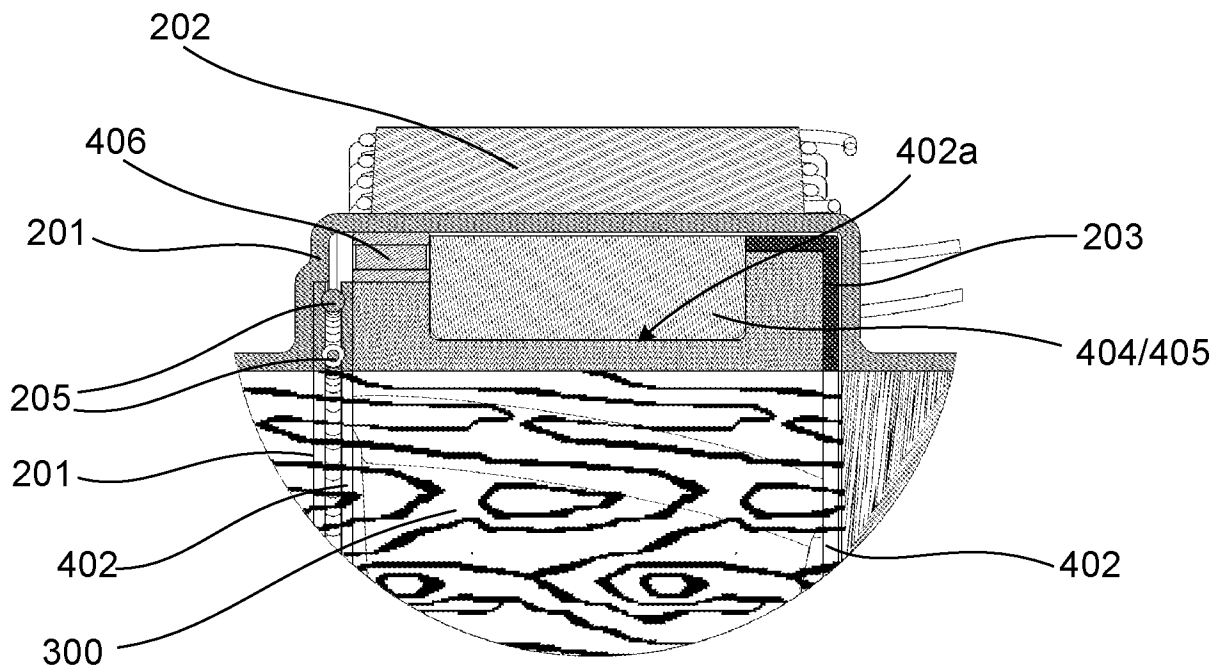


Fig. 3B

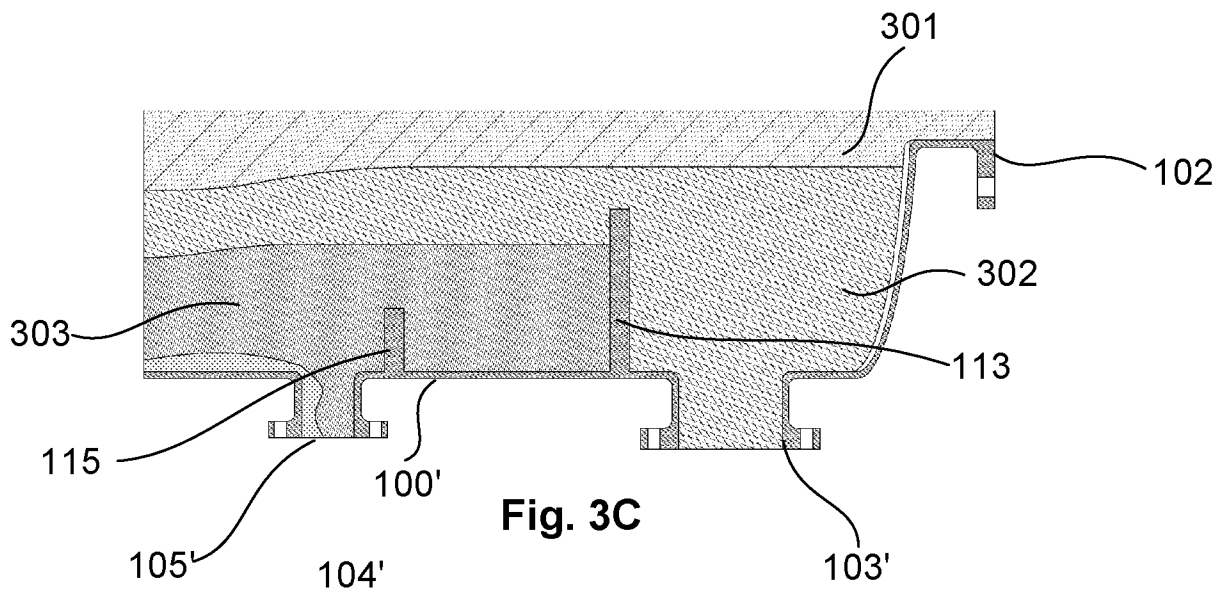


Fig. 3C

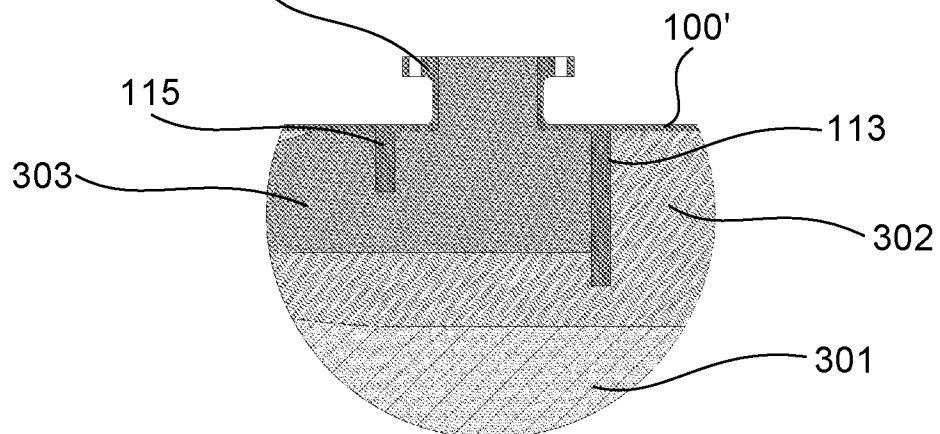


Fig. 3D

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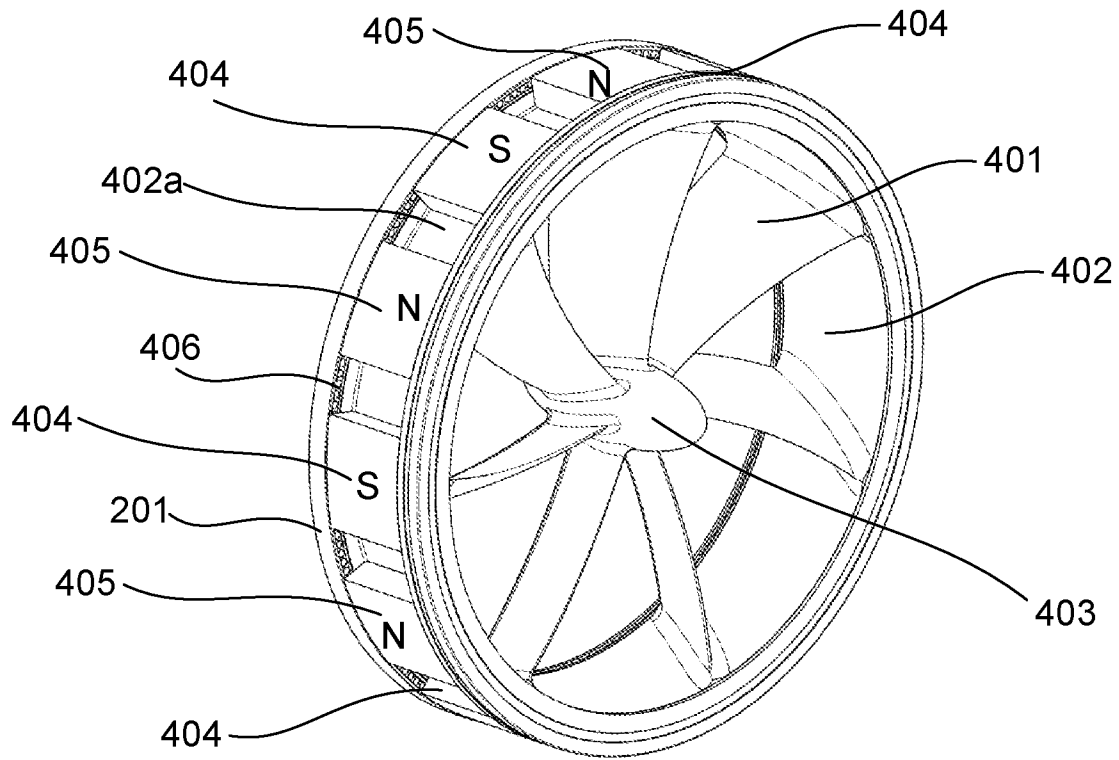


Fig. 4A

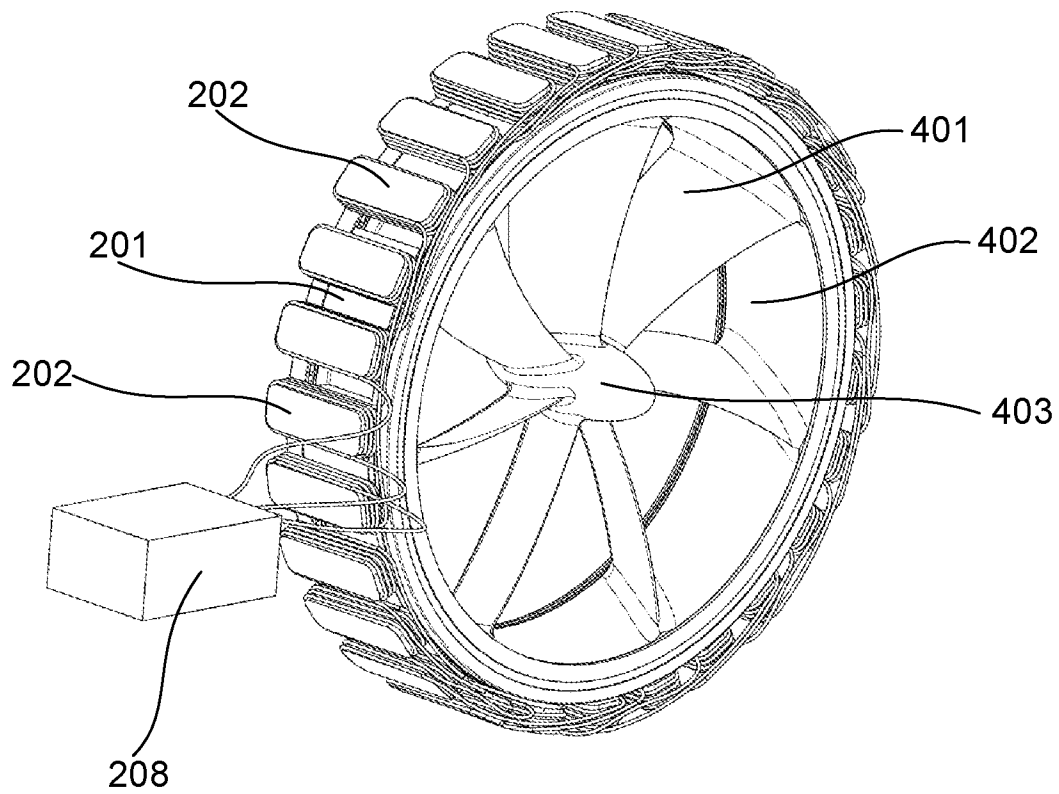


Fig. 4B

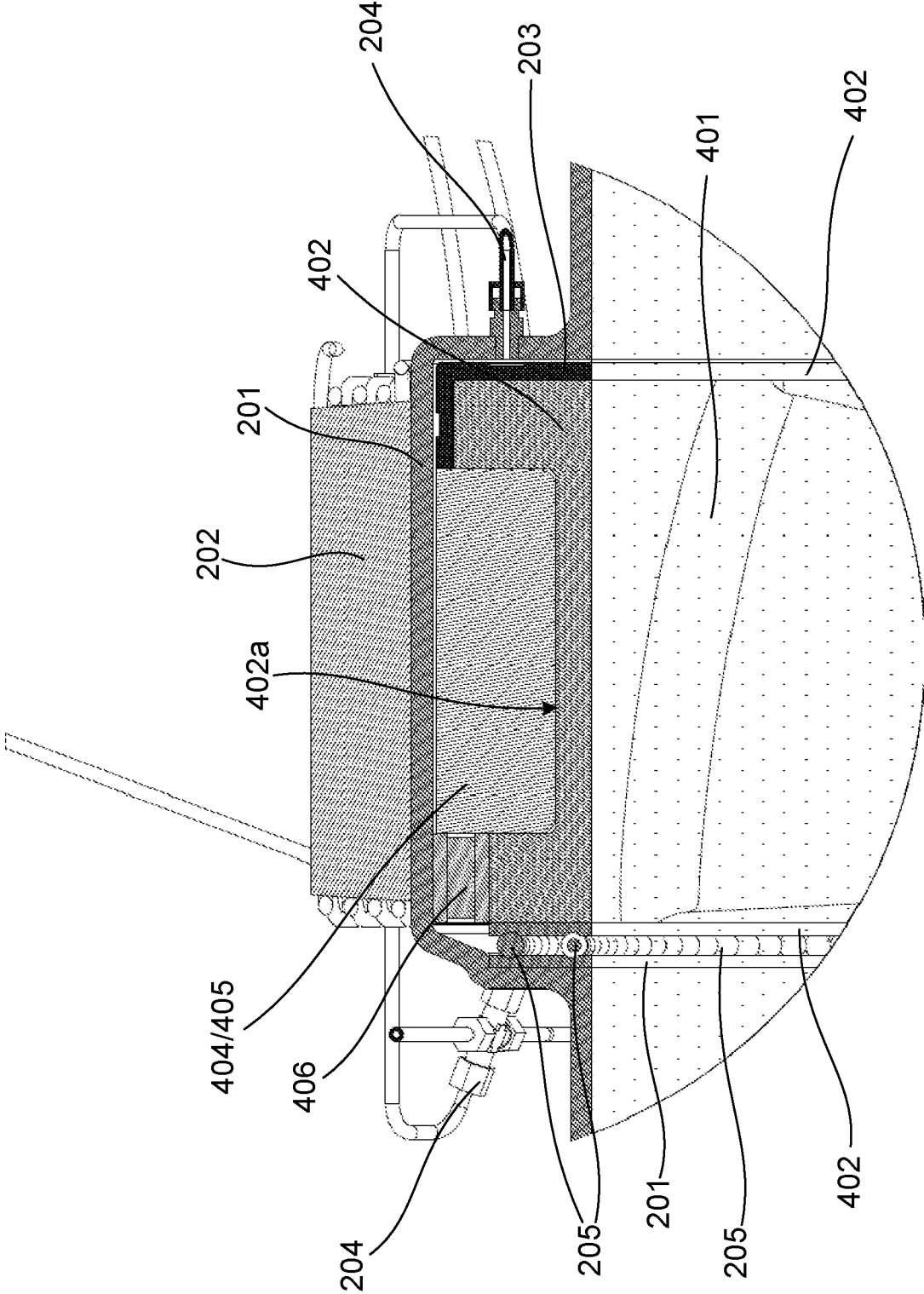
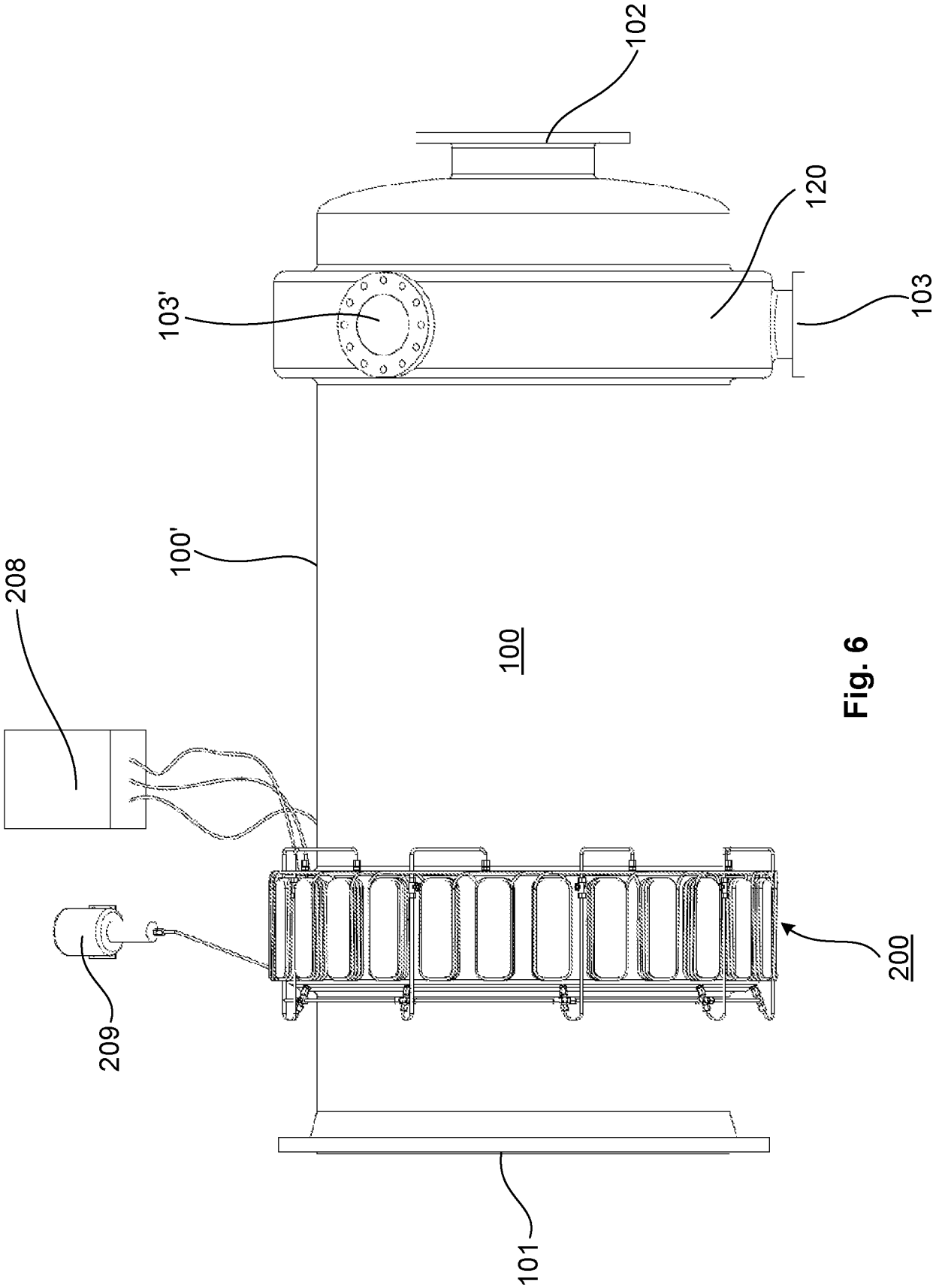
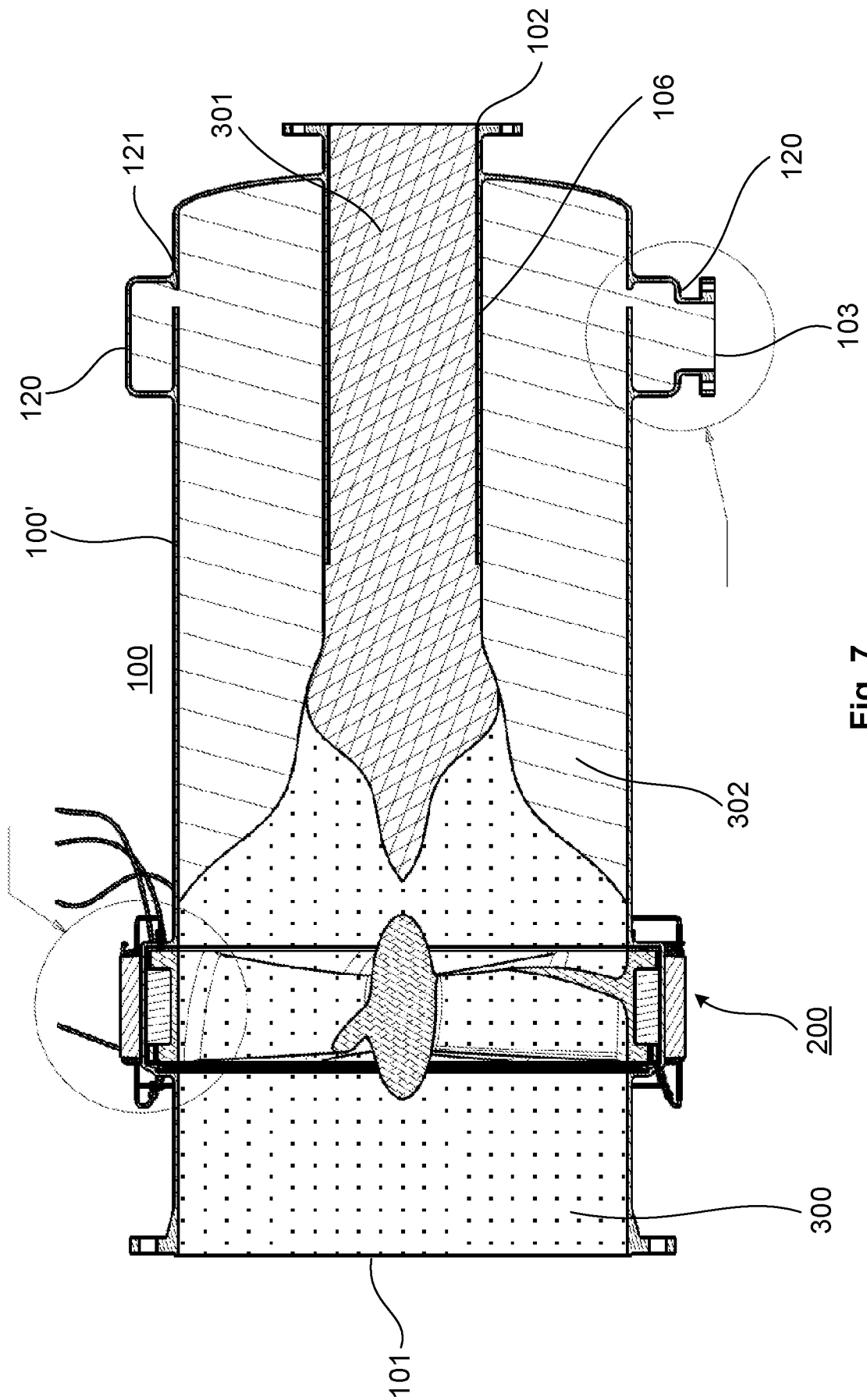
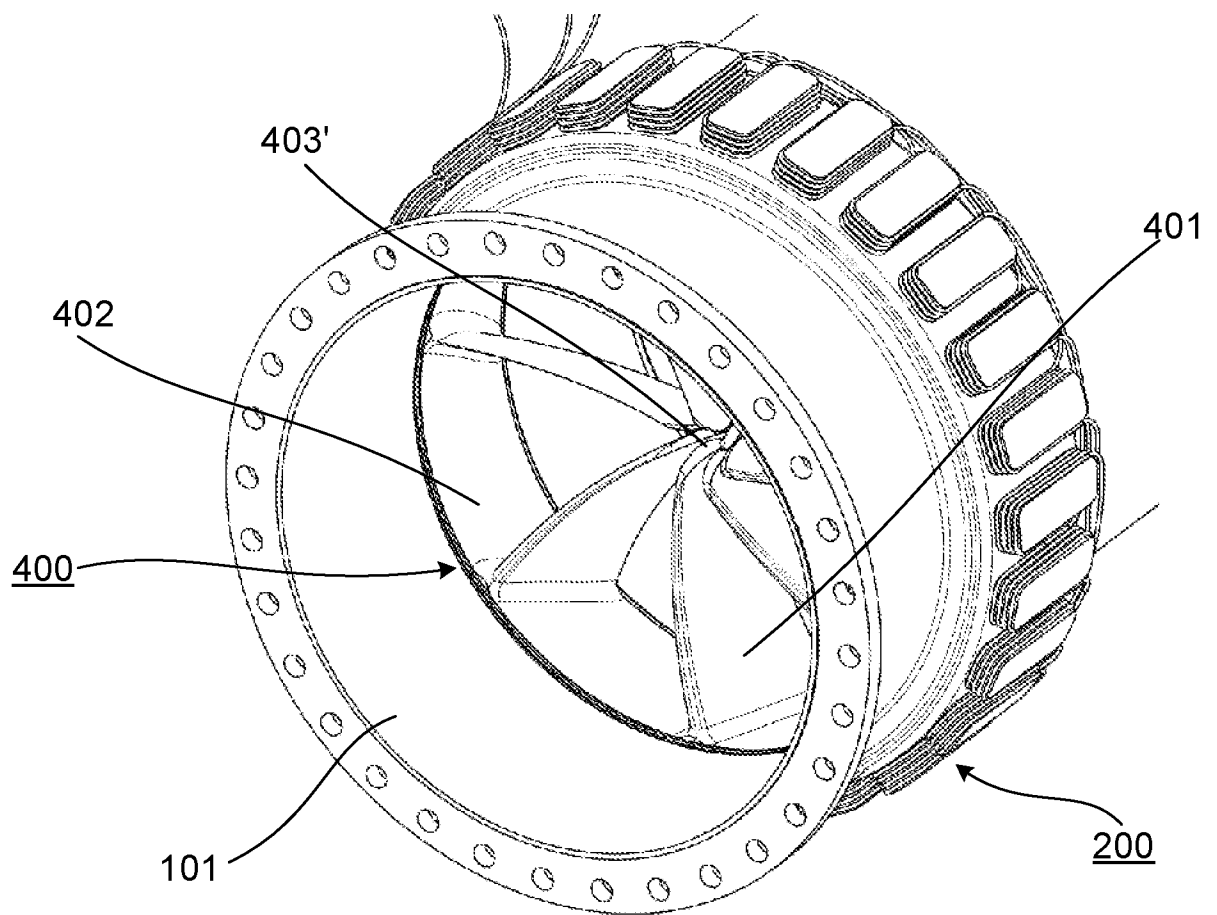
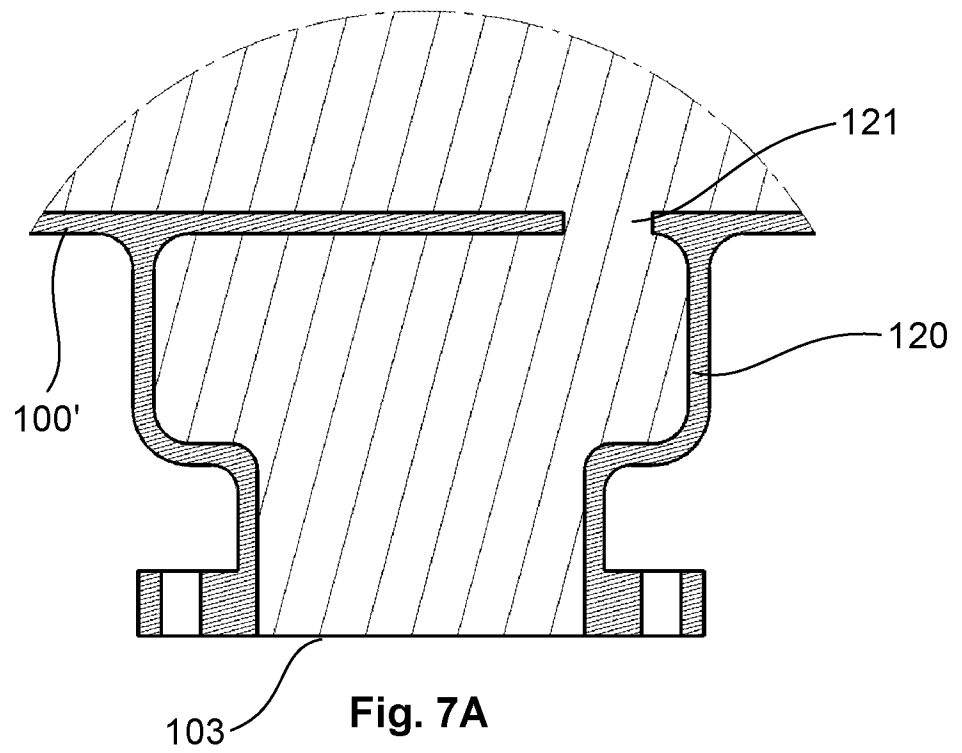


Fig. 5







INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO2018/050191

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: B04B

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 2403650 B1 (ALFA LAVAL CORP AB), 21 December 2016 (2016-12-21); abstract; paragraphs [0025], [0026], [0028]-[0036]; figure 2; claims 1,2,14 --	1-12
A	CN 106824557 A (DALIAN GUANLI MOTOR TECH CO LTD), 13 June 2017 (2017-06-13); figure 1; see WPI & EPODOC abstracts --	1-12
A	WO 2016074950 A1 (VETCO GRAY SCANDINAVIA AS), 19 May 2016 (2016-05-19); page 3, line 18 - page 4, line 10; page 5, line 9 - line 22; figures 5a, 5b, 5c; claim 3 --	1-12



Further documents are listed in the continuation of Box C.



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* Special categories of cited documents:

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Date of the actual completion of the international search

18-09-2018

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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International Patent Classification (IPC)

B04B 5/12 (2006.01)

B04B 7/04 (2006.01)

B04B 9/02 (2006.01)

INTERNATIONAL SEARCH REPORT

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