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(71) Applicant *(for all designated States except US)*: **PAQUES BIO SYSTEMS B.V.** [NL/NL]; Tjalke de Boerstrjitte 24, NL-8561 EL Balk (NL).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **FRANKENA, Douwe** [NL/NL]; Dennenburg 11, NL-8702 AW Bolsward (NL). **VELLINGA, Sjoerd Hubertus Josef** [NL/NL]; Pastoriesingel 23, NL-8458 CP Tjalleberd (NL).

(74) Agent: **KETELAARS, Maarten**; J.W. Frisolaan 13, NL-2517 JS The Hague (NL).

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(54) Title: BIOREACTOR AND METHOD OF MOUNTING A SEPARATOR IN A REACTOR VESSEL

(57) Abstract: The invention relates to a bioreactor (1) comprising a reactor vessel (41) having a reaction chamber (2) located generally above an inlet system (4) for influent or a mixture of influent and recycled material, wherein a separator (17,18) is mounted in the reactor vessel (41) wherein a gas guiding device (130) extends outwardly from the separator (17,19) towards an interior wall of the reactor vessel(41). In an embodiment the gas guiding device (130) comprises a flexible seal(136), the gas guiding device (130) being arranged to bring the seal (136)in contact with the vessel interior wall (41).

Bioreactor and method of mounting a separator in a reactor vessel

The invention relates to a bioreactor comprising a reactor vessel having a reaction chamber located generally above an inlet system for influent or a mixture of influent and recycled material. The invention further relates to a method of mounting a separator in a reactor vessel.

In the field of anaerobic treatment of waste water, reactors having high-load taking capacity have been developed, characterized by high volume loads, a relatively small reaction volume and a slimline high construction. Examples are fluidised bed reactors with e.g. sand as carrier material or adhesion material for the biomass, expanded bed reactors, in which immobilised biomass is present in an expanded bed, and internal circulation reactors, in which biogas formed is used to generate circulation of the reactor contents. Some bioreactors have gas, such as air, oxygen or nitrogen, injected into the reaction chamber.

From EP 0 539 430-B1 a bioreactor is known having a reaction chamber and a mixing chamber. An inlet system allows influent and/or recycled material to enter the reactor vessel through a mixing chamber separated from the reaction chamber by a partition, the partition having slits. In the bioreactor a separator is mounted above the mixing chamber. In other known bioreactors multiple separators are mounted above one another in a reactor vessel. In the reaction chamber the fluid reacts with for example a sludge blanket or sludge bed and fluid of lower density will move upwards and reach the separator.

The separator is mounted in the reactor vessel by placing a ring welded on the interior of the reactor vessel and fixing the separator to the ring using bolts. A sealed connection is necessary for preventing gas to circumvent the separator while the gas traverse the reactor vessel. The seal and/or other parts of the connection between the separator and the interior wall of the reactor vessel form gas guiding elements guiding the gas into an inlet of the separator.

A problem with the known bioreactors are the costs connected to preparing the welded seal for making the connection between the separator and the interior wall. It is a goal of the present invention to provide a more cost effective seal for guiding the gas into the inlet of the separator.

The invention provides an improved bioreactor. A bioreactor is provided, comprising a reactor vessel having a reaction chamber located generally above an inlet system for influent or a mixture of influent and recycled material. In an embodiment the separator, such as a settler, is mounted in the reactor vessel. The separator is mounted above the inlet system, preferably in the reaction chamber. Multiple separators can be mounted in the reaction chamber.

In an embodiment a gas guiding device extends outwardly from the separator towards an interior wall of the reactor vessel. The gas guiding device is arranged to guide fluids and in particular gas towards an inlet of the separator. The gas guiding device according to the invention comprises a flexible seal, the gas guiding device being arranged to push the seal in contact with the vessel interior wall. Instead of a weld a flexible seal is used that is fixed onto the interior wall of the vessel creating a gas tight seal. The gas guiding device comprises elements for a gas-tight and/or fluid-tight connection between the vessel interior wall and the settler, such that fluids and gas can not circumvent the settler in their path upwards towards a top of the bioreactor. According to the invention the gas guiding function and sealing function are combined as a result of using a flexible seal. In an embodiment the flexible seal extends around the complete circumference of the separator. The separator mounted in the reactor vessel has an inlet and from that inlet outwardly extends the gas guiding device and the flexible seal. The flexible seal can be arranged to make a sealed off connection between the separator and the interior wall of the reactor vessel.

In a further embodiment the gas guiding device comprises overlapping plates extending outwardly and having a flexible seal on the outer end. The overlapping plates form a gas tight barrier. The overlapping plates prevent passage of light fluid in particular gas. In an embodiment the overlapping plates form the pushers that push the seal into contact with the interior wall.

It is preferred to have a gas guiding device having guides for guiding the overlapping plates in an outward direction. The guides allow outward movement or shifting of the overlapping plates. The overlapping plates can be moved outwards, and even though the external diameter will increase, the plates will still overlap, providing a gas/fluid tight partition preventing gas/fluid from circumventing the separator.

In a further embodiment the gas guiding device comprises an outwardly extendable diaphragm having a flexible seal on an outward end. Such an arrangement

allows moving the overlapping plates outwardly pushing the seal mounted on the outer ends of the plates into contact with the interior wall, and, if enough force is applied, a gas tight connection can be made.

In a further embodiment the guide comprises a locking element for locking the plates in a position such that the seal engages on the vessel interior wall. In this specific embodiment instead of welding, plates are moved outwardly to make a gas tight seal.

In a preferred embodiment the plates are formed from plastic preferably polypropylene. Use of a plastic material such as polycarbonate reduces costs for providing the gas tight seal.

In a further embodiment the gas guiding device is connected to a lower side of the separator. By providing the gas guiding device at a lower side of the separator all light fluids and gasses can be guided into the inlet of the separator.

In a preferred embodiment a mounting frame is connected to a lower side of the separator, and the gas guiding device is connected to the mounting frame. The mounting frame is in an embodiment mounted at a number of positions on the interior wall of the reactor vessel. In a preferred embodiment a standard bolted tank is used in which only a limited amount of mounting positions are available for mounting the mounting frame. The mounting frame supports the separator.

In an embodiment the gas guiding device extends outwardly and downward. By extending downwardly, the lighter fluid particles such as the gas particles are guided by the gas guiding device, in particular plates of the gas guiding device inwardly towards an inlet of the separator.

In an embodiment the gas guiding device comprises an outward pusher. The pusher is provided with the flexible seal. The pusher is moved outwards to fix the seal into contact with the wall. The pusher can be part of the gas-tight and/or fluid tight connection or can be a separate element. The pusher provides an outward force pushing the seal into contact with the vessel. The pusher can provide the outward force during a limited time. In an embodiment the flexible seal is permanently installed onto the interior vessel walls.

In a preferred embodiment flexible seals are formed by a sealing rubber. Sealing rubber can be extended in length, e.g. by stretching the sealing rubber in an outward direction providing a larger circumference.

In an embodiment the seal has a U-shaped cross section. The receiving part of the U shaped portion receives part of the gas guiding device. This allows easy mounting of the flexible seal onto the gas guiding device. Further this allows a sealed of connection.

In a further embodiment the gas guiding device is arranged to seal off gas passages in the reactor vessel around the separator. This will prevent gas from passing the separator.

According to a further aspect a method of mounting a separator in a reactor vessel of a bioreactor is provided. Further a method of providing a gas seal is provided. In an embodiment of the method a mixing chamber is provided separated by a partition from a reaction chamber in the reactor vessel, said reaction chamber located generally above the mixing chamber. Influent is fed into the mixing chamber. Further mixtures of influent and recycled material can be received in the mixing chamber. A flow of recycled material can be fed to the mixing chamber using a downer.

A reactor vessel is provided having an interior wall. In an embodiment a separator is mounted in the reactor vessel and a connection between the separator and the interior wall is sealed. The connection prevents gas/fluid to circumvent the separator during the upwards flow in the reactor vessel. According to a preferred embodiment sealing the connection comprises pushing a flexible seal outwardly to engage onto the interior wall. Instead of by welding, now a seal is obtained by providing a flexible seal, such as a rubber, and pushing the seal into contact with the interior wall. This can be done at lower costs. The flexible seal can provide a similar gas/fluid tight connection between separator and interior vessel wall, preventing circumvention of the separator.

Although specific embodiments will be described in this disclosure, it will be clear for the skilled person, that the invention is not limited to the specific embodiments. Any of the features described in this disclosure, including the features described with an explicit advantage as well as features having implicit advantages are comprised in this disclosure and can be part of claimed subject matter, in particular of divisional applications.

The invention will further be described referring to the drawing, wherein:

Figure 1 shows a vertical cross section of a bioreactor;

Figures 2a-2c show sectional views of an embodiment of the sealed connection of a separator in reactor vessel;

Figure 3 shows a sectional view of an embodiment of the reactor vessel.

A number of methods are available for wastewater treatment. One of the choices is the manner in which the digestion of organic matter in the wastewater is arranged. This can be done for example through anaerobic digestion, which is a bacterial process that is carried out in the absence of oxygen, or aerobic digestion, which is a bacterial process in the presence of oxygen. Under anaerobic conditions, fermentation takes place in the reaction chamber as a result of contact between sludge granules and water-soluble substances, such as lower fatty acids, and methane is formed.

The bioreactor 1 shown in figure 1 is an anaerobic waste water treatment installation, comprising a reactor vessel 41, inside which is a reaction chamber 2. As is known, a wide range of reactor sizes is possible. Dimensions for cylindrical reactor vessels 41 are about 8-30 meters in height, and 3-15 meters in diameter. Typical dimensions for anaerobic waste water treatment vessels 41 are 20-30 meters of height, and 5-15 meters of diameter. Inside the reaction chamber 2, the contaminated fluid interacts with sludge and in particular the anaerobic bacterial processes take place there.

On the floor 10 of the reaction chamber 2, there is at least one mixing chamber 3, which mixes incoming influent material with partially recycled material. The mixing chamber 3 is designed to introduce a fluid mixture into the reaction chamber 2 for processing. Each mixing chamber 3 receives influent material via an inlet system 4. Influent is pumped 42 from outside into the mixing chamber 3 and is distributed by pipes 43.

The inlet system 4 also comprises the downer 7 connected to the mixing chamber 3. The downer 7 brings recycled material from the higher regions of the bioreactor 1 back into the mixing chamber 3. After it is mixed with the influent material the mixture of new and partially recycled material is brought back into the reaction chamber 2. There is typically one downer 7 for each mixing chamber 3 in the reaction chamber 2.

The mixing chamber 3 in the shown embodiment is essentially box-shaped, with a partition 44 between mixing chamber 3 and reaction chamber 2. The partition or membrane 44 is typically formed by plates 8, for example made of plastic, such as polypropylene. The roof 9 and floor of the mixing chamber 3 are essentially parallel with the reactor vessel floor 10. However, it is possible to envision designs without a

roof, for example in a conical or pyramid shape, and/or without a floor, for example an upside-down pyramid or funnel shape.

As can be seen in Figure 1, the reactor vessel floor 10 is essentially the same as the reaction chamber floor. In this description, the two terms will be used interchangeably.

Outlet 12 is provided in the plates 8 forming a fluid connecting between the mixing chamber 3 and reaction chamber 2, forming the outlets of the inlet system 4 into the mixing chamber 3. The outlet 12 is schematically illustrated in Figure 1.

In the illustrated embodiment, the outlets of the inlet system 4 further comprises one or more gas relieve systems 13, which bring gaseous material out of the mixing chamber 3 into the reaction chamber 2. It is advantageous to locate the relieve system 13 on the roof 9 of the mixing chamber 3, since gaseous material will rise to the top of the mixing chamber 3.

The outlets of the inlet system 4 transfers a fluid mixture of the influent and recycled material into the reaction chamber 2 through partition 44. Inside the reaction chamber 2 the anaerobic reactions will take place. As the influent material is being processed, lighter materials, such as gasses and liquids, will generally rise in the reaction chamber 2.

In the embodiment according to Figure 1, the bioreactor 1 comprises a first stage collection system or separator 17 which is arranged to collect mainly gaseous and liquid materials. A second stage collection system or separator 18 is provided as well. Both collection systems 17 and 18 bring material, via interconnecting riser 19 in the case of the first stage, into the separation chamber 20. This separation chamber 20 will separate gaseous materials from the rest of the material. The gaseous material can exit the chamber via biogas outlet 21. The other materials are collected in the downer 7 and transported, via the inlet system 4 back into the mixing chamber 3. Thus the mixing chamber 3 mixes influent material and partially recycled material. Downer 7 and interconnecting riser 19 are schematically indicated by a line.

In the Figure 1, the downer 7 is attached to the roof 9 of the mixing chamber 3. It may be that the mixing chamber 3 supports the downer 7, or the downer 7 helps to support the mixing chamber 3. Other ways to connect the downer 7 to the mixing chamber 3 are possible as well, for example through an inlet in the side of the mixing

chamber 3. In an embodiment of the invention, not shown in Figure 1, some or all of the influent material is inserted into the downer 7 somewhere between the separation chamber 20 and the mixing chamber 3 and from there transported to the mixing chamber 3.

The reaction chamber 2 further comprises an effluent outlet system 22, for outlet or cleaned liquid materials. The effluent outlet system 22, here a gutter, having a U-shaped cross section, is a collection system and accumulates outlet fluids from the reaction chamber 2, which can then exit the bioreactor via effluent discharge 23. The effluent outlet system is shown only schematically.

In the embodiment according to Figure 1 there are three ways for material to leave the reaction chamber 2. First, cleaned fluids can leave the system through the effluent outlet system 22. Second, a mixture of gas and fluids can enter one of the collection system stages 17 or 18. In this case, the gaseous material will exit the bioreactor through the biogas outlet 21, and the other materials will be sent back to the mixing chamber via downer 7. Third, a mixture of fluid and solid materials may be removed through a sludge discharge system (not shown in figure 1).

Figure 2a shows a side view of an bottom side of a separator 17 positioned inside a reactor vessel 41. Figures 2b and 2c show cross sectional views of the mounting frame 120 that support the separator 17 mounted in the vessel 41. Vessel 41 can be a standard bolted vessel 41. Such vessel can be manufactured at low costs and are therefore advantageous.

The mounting frame 120 is mounted in the vessel 41 at mounting point 121-124 indicated in Figure 3. In the cylindrical vessel 41 these mounting points are mounted at an inside of the vessel and extend inwards from the interior wall of vessel 41. The mounting points 121-124 allow fixation of a mounting frame 120 fixed underneath a separator 17. The mounting frame can comprise interconnected beams supporting a complete bottom surface of the settler 17 allowing fluid to penetrate in between and enter the inlet of the separator 17.

In Figures 2b and 2c illustrate cross sections of embodiments of a radially outward part of a mounting frame 120. Near a bottom side of the separator 17 gas guiding device 130 is mounted, fixed by bolt 131 to the mounting frame 120.

A L-shaped frame comprises a leg 150 and arm 151 connects the gas guiding device to the mounting frame 120. Arm 151 is positioned at an angle with respect to the

horizontal. The angle allows, when fixing the gas guiding device to the arm 151, to further bias the gas guiding device outwardly as a result of a combined upward and outward movement when fixing the gas guiding device to the arm 151.

The gas guiding device 130 comprises a plate 132 comprising a locking bolt 134 At an outward end 154 of plate 132 a flexible seal 136, such as a rubber ring, is provided and as a result of the outward movement 135 of the plate 132, the seal brought into contact with the interior wall 41, creating a sealed off connection.

In an embodiment a guide is provided allowing shifting of the plate 132 in an outward direction 135 towards the interior wall of vessel 41. The guide can allow moving the plate 132 outwards to provide a outward bias on the seal 136, further sealing of the connection.

Seal 136 comprises a round cross section in the embodiment shown. Other cross sections are possible. Further seal 136 comprises a inwardly extending tip 155 received in a cavity on the outward end 154 of the plate. This allows connection of the seal to the gas guiding device and will allow outward biasing of the seal 136 onto the interior wall 41 when fixing the gas guiding device onto the arm 151.

Plate 132 extends from under the separator 17 and extends outwards and downwards. If gas or fluid moves upwards according to arrow 138, the plate 132 will guide the gas inwards, toward the inlet 139 of the separator. Gas/fluid is prevented from passing the separator 17 without entering the inlet 139. Plate 132 and as a result the entire gas guiding device 130 acts as a seal or connection between the separator 17, preventing circumventing the inlet 139 of the separator and forcing all upward moving fluid to enter the inlet 139.Plate 132 is positioned in overlapping arrangement with plate 142 as shown in Figure 2a. A detailed view of plate 142 is shown in figure 5. Plates 132,142 are formed as arches. Plates 132,142 are arranged as a diaphragm, allowing outward movement towards the interior wall of vessel 41, allowing to form a gas tight seal. The overlap of the plates 132,142 prevents gas from penetrating and allows the outward shifting of the plates, without loosing the gas tight connection.

Other embodiments according to the invention use a seal locked into sealing position using an extendible ring. The plates 132, 142 can be polyethylene plates. Two guides 133 and two bolts 134 position the plates 132,142 in the extended position.

Claims

1. Bioreactor (1) comprising a reactor vessel (41) having a reaction chamber (2) located generally above an inlet system (4)for influent or a mixture of influent and recycled material, wherein a separator (17,18) is mounted in the reactor vessel (41) wherein a gas guiding device (130) extends outwardly from the separator (17,19) towards an interior wall of the reactor vessel (41), the gas guiding device (130) comprising a flexible seal (136), the gas guiding device (130) being arranged to bring the seal (136)in contact with the vessel interior wall (41).

2. Bioreactor according to claim 1, wherein the flexible seal (136) extending around the complete circumference of the separator (17,18).

3. Bioreactor according to claim 1 or 2, wherein the gas guiding device (130) comprises overlapping plates (132,142) extending outwardly and having the flexible seal (136) on an outer end (154).

4. Bioreactor according to claim 3, wherein the gas guiding device (130) comprises guides for guiding the overlapping plates in an outward direction.

5. Bioreactor according to claim 4, wherein the guide comprises a locking element for locking the plates in a position such that the seal engages on the vessel interior wall.

6. Bioreactor according to any of the claims 3-5, wherein the plates (132,142) are plastic, preferably polypropylene, plates.

7. Bioreactor according to any of the preceding claims, wherein the gas guiding device (130) comprises an outwardly extendible diaphragm having the flexible seal on an outward end.

8. Bioreactor according to any of the preceding claims, wherein the gas guiding device (130) is connected to a lower side of the separator (17,18).

9. Bioreactor according to claim 8, wherein a mounting frame (120) is connected to the lower side of the separator (17,18), wherein the gas guiding device is connected to the mounting frame (120).

10. Bioreactor according to any of the preceding claims, wherein the gas guiding device extends outwardly and downwards.

11. Bioreactor according to any of the preceding claims, wherein the reactor vessel (41) is a standard bolted tank.

12. Bioreactor according to any of the preceding claims, wherein the gas guiding device (130) comprises an outward pusher provided with the seal, the outward pusher being arranged to push the seal outwardly into contact with the vessel interior wall.

13. Bioreactor according to any of the preceding claims, wherein the flexible seal (136) is formed by a sealing rubber.

14. Bioreactor according to any of the preceding claims, wherein the gas guiding device (130) is arranged to seal off gas passages in the reactor vessel around the separator (17,18).

15. Method of mounting a separator in a reactor vessel and providing a gas seal comprising, providing a reactor vessel having an interior wall, mounting a separator in the reactor vessel and sealing a connection between the separator and the interior wall, wherein sealing comprises pushing a flexible seal outwardly to engage onto the interior wall.

Fig 1

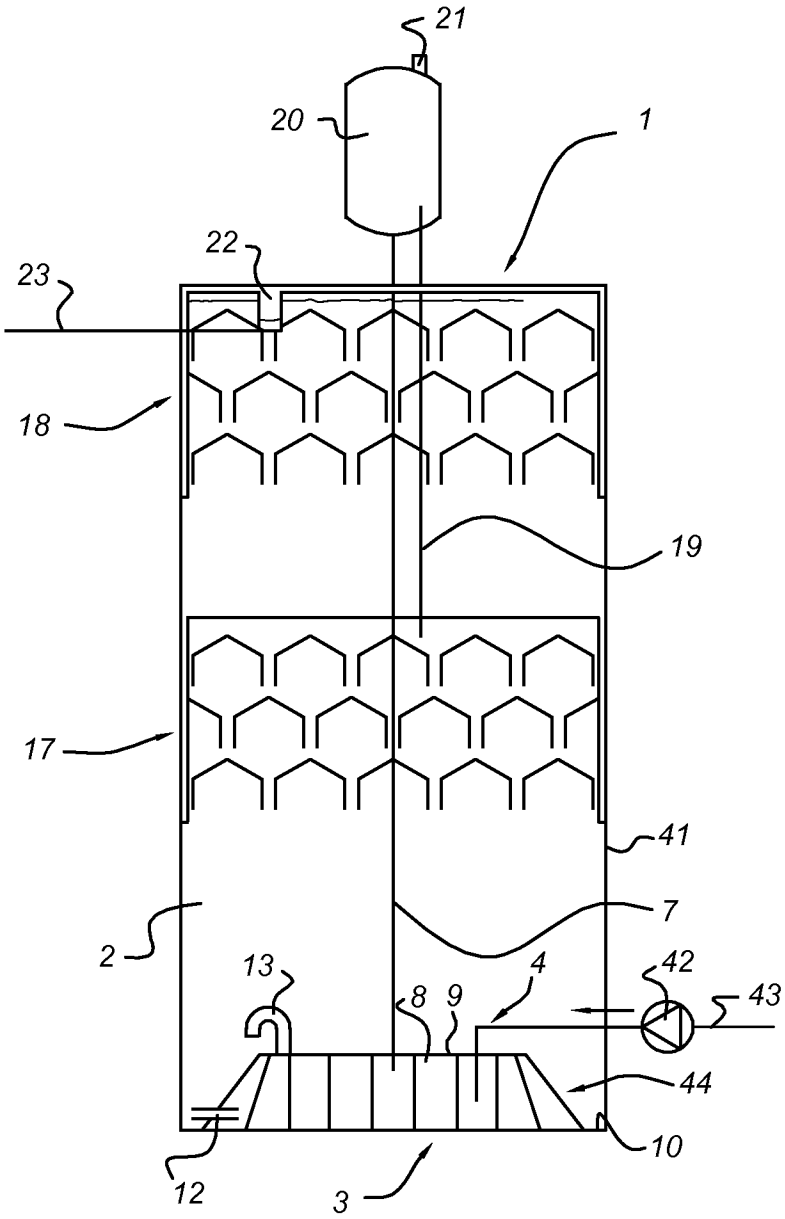


Fig 2a

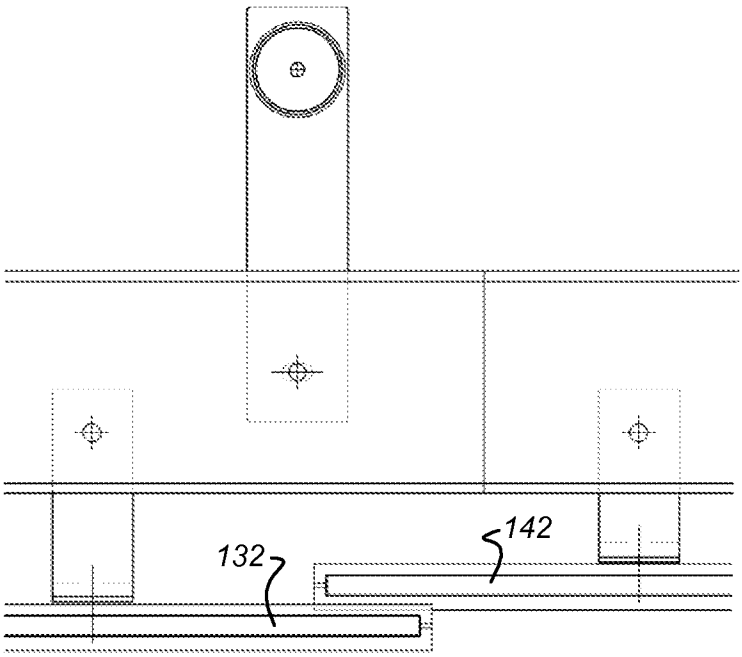


Fig 2b

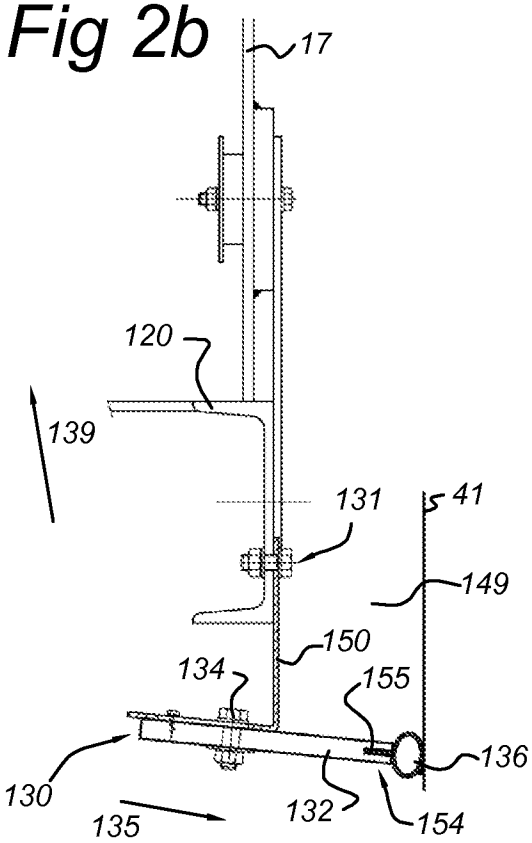


Fig 2c

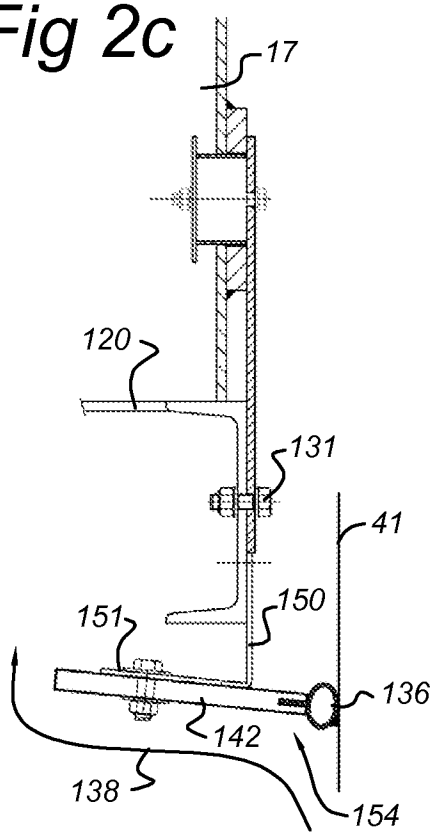
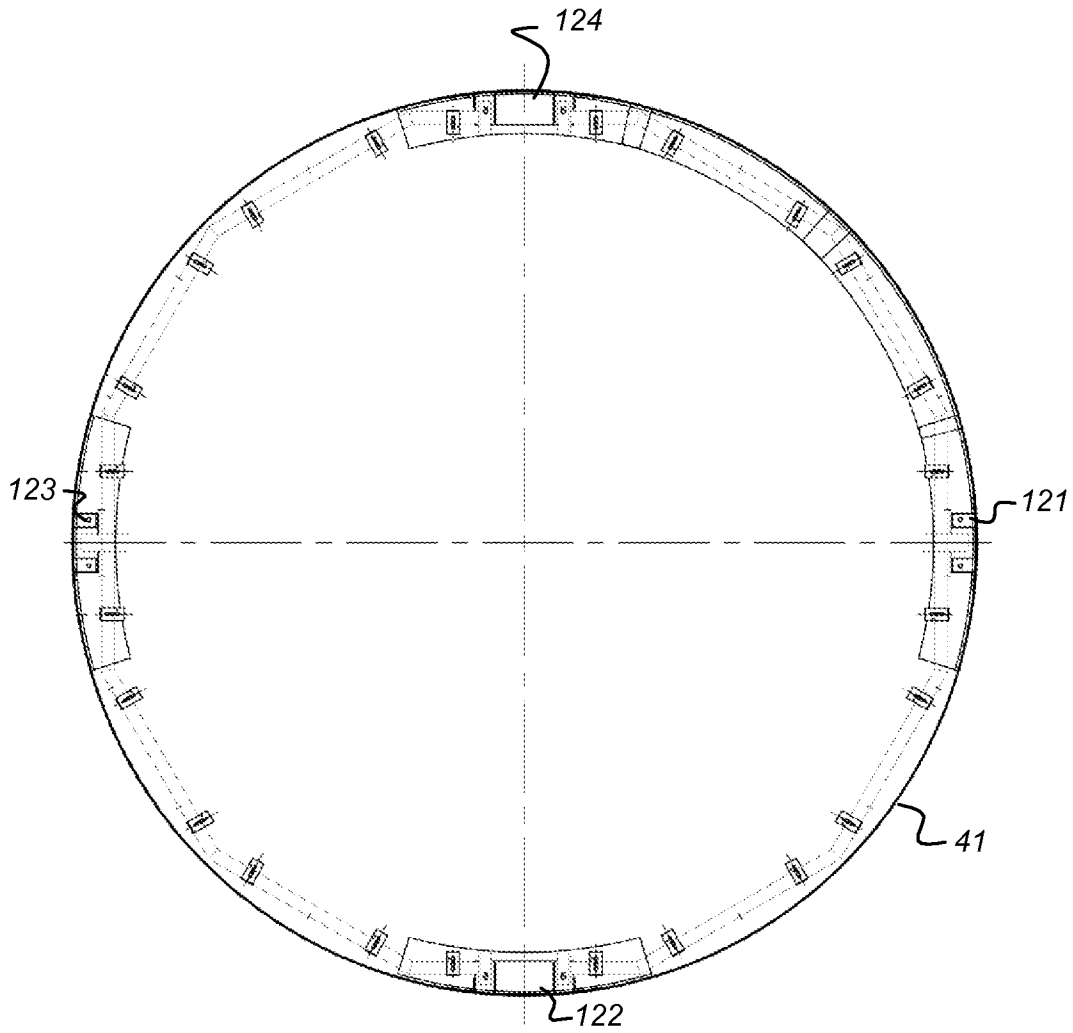


Fig 3



INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2010/050255

A. CLASSIFICATION OF SUBJECT MATTER
INV. C02F3/28
ADD.

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)
C02F

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 practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	WO 03/035560 A (COUNCIL SCIENT IND RES [IN]) 1 May 2003 (2003-05-01) page 15, line 8 - line 11	1
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A	US 3 006 740 A (MAGGIO VINCENT A) 31 October 1961 (1961-10-31) column 2, line 8 - line 15	1

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
27 July 2010	03/08/2010

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Clement, Jean-Paul

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2010/050255

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 622 147 A (VELLINGA SJOERD H J [NL]) 11 November 1986 (1986-11-11) claim 1 -----	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

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