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Pressure vessel

Technical field of the invention

The present invention relates to a pressure vessel in accordance with claim 1. More particularly, the invention relates to a pressure vessel that can be used
5 for processing gas that contains hydrocarbons for use as a fuel in an internal combustion engine.

Background of the invention

When crude oil is pumped from the ground, the oil is usually accompanied with
10 gas. The gas comprises methane, but often also significant amounts of other components, such as heavier hydrocarbons, water and hydrogen. Because of the varying composition of the associated gas that is separated from crude oil, the associated gas is conventionally flared. Flaring of the associated gas in offshore oil drilling facilities is a major environmental problem causing signifi-
15 cant CO₂ emissions. In addition, valuable resources are wasted when the gas is not utilized as an energy source.

A solution to the problem of the varying composition and low quality of the associated gas is to use gas reformers, where heavier hydrocarbons of the gas are converted to synthesis gas (H₂ + CO) and finally to methane (CH₄). The
20 associated gas can thus be utilized in the oil production facilities for reliably, flexibly and efficiently producing electricity with dual fuel or gas engines. Dual fuel engines are often preferred due to their flexibility. With the help of gas reformers, also recovered volatile organic compounds (VOCs) that are generated when the crude oil is heated to improve its viscosity and stranded gas can be
25 utilized in the oil production facilities for producing electricity.

With the gas reformers, the self-sufficiency of the oil production facilities can be improved and the need for fuel bunkering, which is costly in offshore locations, can be reduced. Gas reformers are also beneficial in onshore applications, for instance in remote locations lacking gas pipelines and electricity grid.
30 However, in many applications the limited space complicates the use of gas reformers. Also the maintenance of the gas reformers can be problematic.

Summary of the invention

The object of the present invention is to provide an improved pressure vessel for processing gas that contains hydrocarbons for use as a fuel in an internal combustion engine. The characterizing features of the pressure vessel according to the invention are given in claim 1.

A pressure vessel according to the invention comprises a gas inlet that is located in an upper portion of the pressure vessel when the pressure vessel is in the intended operating position, and a gas outlet that is located in a lower portion of the pressure vessel when the pressure vessel is in the intended operating position. The pressure vessel comprises a lower half and an upper half, the upper half being removably attached to the lower half. The gas inlet is arranged in the upper half of the pressure vessel, the gas outlet is arranged in the lower half of the pressure vessel, and the pressure vessel comprises a partition wall that is arranged between the lower half and the upper half.

Because of the construction, the pressure vessel can replace two separate pressure vessels, which reduces the footprint of a pressure vessel arrangement where two vessels are needed. Also the amount of material needed for the equipment can be reduced and piping around the pressure vessel shortened. The invention is advantageous especially in the case of pressure vessels that are filled with a catalyst material, since the construction allows easier filling of the pressure vessel.

According to an embodiment of the invention, the partition wall comprises a first wall element that is attached to the lower half of the pressure vessel and a second wall element that is attached to the upper half of the pressure vessel. This allows the filling of both halves of the pressure vessel for instance with a catalyst material and transportation of the pressure vessel in two parts without a risk of losing the filling material.

According to an embodiment of the invention, the partition wall comprises a plurality of openings for establishing fluid communication between the upper half and the lower half of the pressure vessel. In certain applications, the two halves of the pressure vessel can thus be connected without external piping.

According to an embodiment of the invention, the upper end of the lower half of the pressure vessel is provided with a first flange and the lower end of the

upper half of the pressure vessel is provided with a second flange that is configured to be attached to the first flange. The flanges function as means for attaching the two halves of the pressure vessel to each other.

5 According to an embodiment of the invention, an upper portion of the upper half is provided with a first gas inlet, an upper portion of the lower half is provided with a second gas inlet, a lower portion of the upper half is provided with a first gas outlet, and a lower portion of the lower half is provided with a second gas outlet. This kind of pressure vessel can be used when a connection through the partition wall is not suitable.

10 According to an embodiment of the invention, a lower portion of the lower half of the pressure vessel is provided with a partition element that is horizontal in the intended operating position of the pressure vessel and separates a lower end portion from the rest of the pressure vessel, the partition element comprising a plurality of openings for establishing fluid communication between the
15 lower end portion and the rest of the pressure vessel and the gas outlet opening to the lower end portion. The partition element allows filling of the pressure vessel for instance with a catalyst material without a risk that the material blocks the outlet.

20 According to an embodiment of the invention, an upper portion of the upper half of the pressure vessel is provided with a partition element that is horizontal in the intended operating position of the pressure vessel and separates an upper end portion from the rest of the pressure vessel, the partition element comprising a plurality of openings for establishing fluid communication between the upper end portion and the rest of the pressure vessel and the gas
25 inlet opening to the upper end portion. The partition element allows filling of the pressure vessel for instance with a catalyst material without a risk that the material blocks the inlet.

30 According to an embodiment of the invention, one of the upper half and the lower half of the pressure vessel is configured to work as a reformer and the other is configured to work as a methanator. According to another embodiment of the invention, each of the upper half and the lower half of the pressure vessel is configured to work as a desulphurization vessel.

Brief description of the drawings

Embodiments of the invention are described below in more detail with reference to the accompanying drawings, in which

Fig. 1 shows a pressure vessel according to an embodiment of the invention,

- 5 Fig. 2 shows a cross-sectional view of the pressure vessel of figure 1 taken along line A–A,

Fig. 3 shows a cross-sectional view of the pressure vessel of figure 1 taken along line B–B in figure 2,

- 10 Fig. 4 shows a pressure vessel according to another embodiment of the invention,

Fig. 5 shows a cross-sectional view of the pressure vessel of figure 4 taken along line A–A,

Fig. 6 shows a cross-sectional view of the pressure vessel of figure 4 taken along line B–B in figure 5,

- 15 Fig. 7 shows a cross-sectional view of a detail of the pressure vessel of figure 1,

Fig. 8 shows a cross-sectional view of a detail of the pressure vessel of figure 4,

- 20 Fig. 9 shows a power generating system where the pressure vessel of figure 4 can be used, and

Fig. 10 shows a power generating system where the pressure vessel of figure 1 can be used.

Description of embodiments of the invention

- 25 Figures 9 and 10 show two examples of the use of gas reformers.

In figure 9 is shown schematically a power generating system that comprises an internal combustion engine 100 that is arranged to drive a generator 101

coupled to the engine 100. The engine 100 is configured to be operable using gaseous fuel that has been processed in a gas reformer. The engine 100 is a piston engine comprising a plurality of cylinders. In figure 9, the engine 100 is a dual fuel engine that can be operated using either liquid fuel or a combination
5 of gaseous fuel and liquid fuel. When gaseous fuel is used as a main fuel, the liquid fuel is used as a pilot fuel for igniting the gaseous fuel. The liquid fuel is supplied to the engine 100 via a liquid fuel feed pipe 113.

Gas is supplied to the power generating system via a fuel supply line 114. The gas contains hydrocarbons. At least part of the gas is heavier hydrocarbons
10 than methane, for instance ethane or propane. The gas can also comprise other components, such as nitrogen, water, carbon dioxide and sulfur compounds. The gas can be, for instance, associated gas from oil drilling, stranded gas or volatile organic compounds (VOCs) recovered from oil/gas production process. Before being used as a fuel in the internal combustion engine 100,
15 the gas is processed to improve its quality and to enhance the efficiency of the engine 100 and the power production.

The compressibility of a fuel gas can be expressed as a methane number. A higher methane number means better compressibility. The methane number of pure methane is 100. If the methane number of the fuel is low, the compression ratio of the engine needs to be lower to prevent knocking, i.e. premature
20 ignition of the fuel. The heavier hydrocarbons have a low methane number. For instance, the methane number of ethane is 43 and the methane number of n-butane is only 10. Usually a methane number of at least 80 is needed for efficient operation of an engine. The methane number is increased by converting
25 the non-methane hydrocarbons to synthesis gas ($H_2 + CO$) and finally to methane (CH_4) in a reformer 104.

In the reformer 104, the hydrocarbons react with steam in the presence of a catalyst. The temperature in the reformer 104 is 300–420 °C and pressure 7–10 barg. The design pressure of the reformer 104 is 11 barg. The reformer 104
30 is thus configured to withstand a pressure difference of at least 11 bar. In the embodiment of figure 9, the reformer 104 is filled with a material comprising a Ni-based catalyst. Also some other catalysts could be used in the process instead of or in addition to the Ni-based catalyst. The Ni-based catalyst is sensitive to sulfur compounds, and therefore the sulfur compounds need to be removed from the gas before the gas is processed in the reformer 104.
35

The power generating system is provided with a first desulfurization vessel 102 and a second desulfurization vessel 103. The desulfurization vessels 102, 103 are filled with a desulfurization absorbent, which absorbs sulfur compounds from the gas. The absorbent is ZnO and the chemical reaction taking place in the desulfurization vessels 102, 103 is $\text{ZnO} + \text{H}_2\text{S} \rightarrow \text{ZnS} + \text{H}_2\text{O}$. The reaction takes place mainly in the first desulfurization vessel 102 and the second desulfurization vessel 103 acts as guard. From the second desulfurization vessel 103, the gas is fed into the reformer 104. Temperature in the desulfurization vessels 102, 103 is 250–350 °C. Also the desulfurization vessels 102, 103 are configured to withstand a pressure difference of at least 11 bar. The power generating system is provided with a first heat exchanger 106 and a second heat exchanger 107. The first heat exchanger 106 receives processed gas from the reformer 104. The second heat exchanger 107 receives processed gas from the first heat exchanger 106. The second heat exchanger 107 also receives unprocessed gas upstream from the first desulfurization vessel 102. The first heat exchanger 106 receives desulfurized gas from the second desulfurization vessel 103. The heat exchangers 106, 107 are thus configured to lower the temperature of the processed gas. In addition the second heat exchanger 107 is configured to increase the temperature of the unprocessed gas and the first heat exchanger 106 is configured to increase the temperature of the desulfurized gas.

From the first heat exchanger 106 the desulfurized gas is introduced into an electric heater 105, where the temperature of the gas is further increased before the gas is supplied into the reformer 104. Instead of the electric heater 105, some other means could naturally be used for increasing the temperature of the gas before the reformer 104.

From the second heat exchanger 107, the processed gas is introduced into a condenser/separator 108. In the condenser/separator 108, water is removed from the processed gas. Also the temperature of the processed gas is further lowered. The condenser/separator 108 receives cooling water from a cooling water inlet duct 111 of the engine 100. The condensed water is supplied into a fresh water line 115. The amount of fresh water needed in the processing of the gas can be decreased by recirculating the water. The cooling water from the condenser/separator 108 is returned to a cooling water outlet duct 112 of the engine 100. The processed gas is introduced from the condenser/separator 108 into a gas valve unit 109, which controls the gas flow to the

engine 100. The temperature of the gas in the gas valve unit 109 is approximately 50 °C.

5 The fresh water that is needed for generating the steam used in the process is introduced into the process via the fresh water line 115. The water is heated in an exhaust gas boiler 110. The heat for generating the steam is taken from the exhaust gases of the engine 100. The exhaust gases are fed into the exhaust gas boiler 110 via an exhaust duct 116. The steam is introduced into the gas stream between the second desulfurization vessel 103 and the first heat exchanger 106.

10 Figure 10 shows a power generating system for a hydrocarbon mixture having low methane content. The system comprises an engine 100 that is arranged to drive a generator 101. The system of figure 9 is suitable for gases having a methane number of at least 40 and a total amount of non-methane hydrocarbons below 80 mol-%. The system of figure 10 is suitable even for gases containing no methane at all and having a methane number around 20. Such gases can be, for instance, natural gas liquids or liquefied VOCs recovered from tankers and carriers during venting and unloading of cargo. The system of figure 10 is similar to the system of figure 9. The main difference is that the heavier hydrocarbons are converted to methane in two separate phases. The system comprises a reformer 104, which operates at higher temperature and converts the heavier hydrocarbons to synthesis gas. The system further comprises a methanator 117, which operates at lower temperatures and converts the synthesis gas to methane-rich gas.

25 A fuel supply line 114 supplies the hydrocarbon mixture, which may be at least partly liquid, to an evaporator 118. The fuel is evaporated and supplied to an electric heater 105, where the temperature of the gas is increased. The gas is then introduced into a desulfurization vessel 102, where sulfur compounds are removed from the gas. Only one desulfurization vessel 102 is shown, but the system could also comprise two or more desulfurization vessels arranged in series. The desulfurization vessel 102 works in the same manner as in the system of figure 9. From the desulfurization vessel 102 the gas is supplied into the reformer 104, where the non-methane hydrocarbons are converted to synthesis gas. Temperature in the reformer 104 is 360–450 °C.

A heat exchanger 106 is arranged between the desulfurization vessel 102 and the reformer 104. In the heat exchanger 106, heat is transferred from the synthesis gas to the desulfurized gas. The synthesis gas is fed from the heat exchanger 106 into the methanator 117, where the synthesis gas is converted to methane-rich gas. Temperature in the methanator 117 is 300–350 °C. The gas from the methanator 117 is supplied to the evaporator 118, where the heat of the gas is used for evaporating the unprocessed fuel and the temperature of the processed gas is decreased. The gas is further fed to a condenser 108, which removes water from the gas. The condenser 108 receives cooling water from a cooling water inlet duct of the engine 100 and returns it into a cooling water outlet duct of the engine 100. The gas is supplied from the condenser 108 to a gas valve unit 109 and further to the engine 100.

The steam needed in the reformer 104 is produced in a boiler 119. In the embodiment of figure 10, the boiler 119 is a multi-fuel boiler, which uses the fuel to be processed as an energy source together with a surplus gas that is fed into the boiler via a gas supply line 120. The boiler 119 may be additionally connected to a back-up fuel source. Instead of the multi-fuel boiler, an exhaust gas boiler can be used for generating the steam. The steam is supplied from the boiler 119 into the gas stream between the desulfurization vessel 102 and the heat exchanger 106.

In figure 1 is shown a pressure vessel 1 according to an embodiment of the invention. Figure 2 shows a cross-sectional view of the pressure vessel 1 taken along line A–A of figure 1. Figure 3 shows a cross-sectional view of the pressure vessel 1 taken along line B–B of figure 2. The pressure vessel 1 of figure 1 can be used as a reformer-methanator unit in the power generating system of figure 10. The pressure vessel 1 comprises a lower half 1a and an upper half 1b. The expressions “lower” and “upper” refer to the intended operation position of the pressure vessel 1. Thus, when the pressure vessel 1 is in use, the upper half 1b is arranged on top of the lower half 1a. The pressure vessel 1 is configured to be used in a vertical position, in which the longitudinal axis 2 of the pressure vessel 1 is vertical. In the embodiment of figure 1, the volume of the upper half 1b is the same as the volume of the lower half 1a of the pressure vessel 1. However, the height of the upper half 1b could differ from the height of the lower half 1a. The upper half 1b of the pressure vessel 1 can thus have a different volume than the lower half 1a. The diameters of the upper half

1a and the lower half 1b needs to be equal at least in those ends of the two halves 1a, 1b that are arranged against each other.

The lower half 1a of the pressure vessel 1 is provided with a first flange 3, which is arranged at the upper end of the lower half 1a. The upper half 1b of the pressure vessel 1 is provided with a second flange 4, which is arranged at the lower end of the upper half 1b. Each of the flanges 3, 4 is provided with holes 5, 6, which can receive bolts 8 for attaching the upper half 1b to the lower half 1a. The upper half 1b of the pressure vessel 1 is thus removably attached to the lower half 1a of the pressure vessel 1.

10 The pressure vessel 1 comprises a partition wall 7, which is arranged between the lower half 1a and the upper half 1b. The partition wall 7 is horizontal when the pressure vessel 1 is in the operating position and divides the pressure vessel 1 into a lower compartment and an upper compartment. The partition wall 7 comprises a first wall element 7a and a second wall element 7b. The first wall element 7a is attached to the lower half 1a of the pressure vessel 1 and the second wall element 7b is attached to the upper half 1b of the pressure vessel 1. The attachment of the wall elements 7a, 7b can be seen in more detail in figure 7. The wall elements 7a, 7b are provided with holes 10, 11 for allowing attachment of the wall elements 7a, 7b to the pressure vessel 1. Also the flanges 3, 4 of the lower half 1a and the upper half 1b of the pressure vessel 1 are provided with holes 12, 13, and the wall elements 7a, 7b can be attached to the flanges 3, 4 by means of bolts 14, 15. The first wall element 7a closes the upper end of the lower half 1a of the pressure vessel 1 and the second wall element 7b closes the lower end of the upper half 1b of the pressure vessel 1.

25 The compartment formed inside the upper half 1b of the pressure vessel 1 is used as a reformer 104. The compartment formed inside the lower half 1a of the pressure vessel 1 is used as a methanator 117. The pressure vessel 1 thus forms an integrated reformer-methanator unit. The gas to be processed is fed into the reformer 104 via a first gas inlet 20. The side wall of the upper half 1b of the pressure vessel 1 is provided with a first inlet opening 18, through which a first inlet pipe 16 is inserted. The first inlet opening 18 is arranged in an upper portion of the upper half 1b of the pressure vessel 1, i.e. close to the upper end of the upper half 1b. The first inlet pipe 16 protrudes into the pressure vessel 1. The first gas inlet 20 is arranged at the end of the first inlet pipe 16.

A first outlet opening 24 is arranged in the side wall of a lower portion of the upper half 1b of the pressure vessel 1. A first outlet pipe 22 is inserted through the first outlet opening 24 and protrudes into the pressure vessel 1. A first gas outlet 26 is arranged at the end of the first outlet pipe 22. Through the first gas
5 inlet 20 the gas to be processed can be fed into the reformer part 104 of the pressure vessel 1. Through the first outlet 26, the synthesis gas can flow out of the reformer 104.

The side wall of the lower half 1a of the pressure vessel 1 is provided with a second inlet opening 19, through which a second inlet pipe 17 is inserted. The
10 second inlet opening 19 is arranged in an upper portion of the lower half 1a of the pressure vessel 1, i.e. close to the upper end of the lower half 1a. The second inlet pipe 17 protrudes into the pressure vessel 1. A second gas inlet 21 is arranged at the end of the second inlet pipe 17. A second outlet opening 25 is arranged in the side wall of a lower portion of the lower half 1a of the pressure
15 vessel 1. A second outlet pipe 23 is inserted through the second outlet opening 25 and protrudes into the pressure vessel 1. A second gas outlet 27 is arranged at the end of the first outlet pipe 25. Through the second inlet 21, the synthesis gas can be introduced into the methanator part 117 of the pressure vessel and through the second outlet 27 the methane-rich gas can flow out of
20 the methanator 117.

An upper portion of the upper half 1b of the pressure vessel 1 is provided with a partition element 29, which separates an upper end portion 30 from the rest of the pressure vessel 1. The partition element 29 is provided with openings for establishing fluid communication between the upper end portion 30 and the
25 rest of the upper half 1b of the pressure vessel 1. In the embodiment of the figures, the partition element 29 is a net. A lower portion of the upper half 1b of the pressure vessel 1 is provided with a similar partition element 31, which separates a lower end portion 32 from the rest of the pressure vessel 1. The upper half 1b of the pressure vessel 1 between the nets 29, 31 is filled with the
30 catalyst material. The end portions 30, 32 are filled with alumina balls. The nets 29, 31 hold the alumina balls in the end portions 30, 32. The first gas inlet 20 opens to the upper end portion 30 and the first gas outlet 26 opens to the lower end portion 32.

The construction of the lower half 1a of the pressure vessel 1 is similar. An up-
35 per portion of the lower half 1a is provided with a partition element 35, which

separates an upper end portion 36 from the rest of the lower half 1a of the pressure vessel 1. A lower portion of the lower half 1a is provided with a partition element 33, which separates a lower end portion 34 from the rest of the lower half 1a of the pressure vessel 1. Also the lower half 1a of the pressure vessel 1 is filled with the catalyst material between the partition elements 33, 35 and the end portions 34, 36 are filled with alumina balls. The second gas inlet 21 opens to the upper end portion 36 and the second gas outlet 27 opens to the lower end portion 34 of the lower half 1a of the pressure vessel 1.

With the pressure vessel of figure 1, the footprint of the reformer 104 and the methanator 117 can be reduced. Since the reformer 104 and the methanator 117 work at the substantially same pressure, the partition wall 7 does not need to withstand a great pressure difference. Consequently, it can be a relatively light part, and material is saved compared to two separate pressure vessels, where both ends of the pressure vessels have to carry significant forces. Because the partition wall 7 comprises separate wall elements 7a, 7b for the upper half 1b and the lower half 1a of the pressure vessel 1, the pressure vessel 1 is easy to divide into two parts and the parts can be transported for instance from an offshore location to service facilities, where the catalyst material is exchanged. The pressure vessel 1 is also easy to fill through the open ends of the upper half 1b and the lower half 1a.

Figure 4 shows a pressure vessel 1 according to another embodiment of the invention. Figure 5 shows a cross-sectional view of the pressure vessel 1 taken along line A–A of figure 4. Figure 6 shows a cross-sectional view of the pressure vessel 1 taken along line B–B of figure 5. The pressure vessel 1 of figure 4 can be used as a desulfurization unit in the power generating system of figure 9. Both the first desulfurization vessel 102 and the second desulfurization vessel 103 can be integrated in the pressure vessel 1 of figure 4. The construction of the pressure vessel of figures 4 to 6 is similar to the construction of the pressure vessel of figures 1 to 3. The main differences are that the pressure vessel 1 of figures 4 to 6 is provided with only one gas inlet and one gas outlet and that the compartments 102, 103 inside the upper half 1b and the lower half 1a of the pressure vessel 1 are in fluid communication with each other through the partition wall 7. Also the pressure vessel 1 of figures 4 to 6 is configured to withstand a pressure difference of at least 11 bar. The temperature inside the pressure vessel 1 is 200–400 °C.

In the embodiment of figures 4 to 6, the pressure vessel 1 comprises an inlet opening 18 that is arranged in an upper portion of the upper half 1b of the pressure vessel 1. An inlet pipe 16 is inserted through the inlet opening 18 and protrudes into the pressure vessel 1. A gas inlet 20 is arranged at the end of the inlet pipe 16. The pressure vessel 1 further comprises an outlet opening 25 that is arranged in a lower portion of the lower half 1a of the pressure vessel 1. An outlet pipe 23 is inserted through the outlet opening 25 and protrudes into the pressure vessel 1. A gas outlet 27 is arranged at the end of the outlet pipe 23. Through the gas inlet 20 the gas to be desulfurized is introduced into the upper half 1b of the pressure vessel 1, which functions as a first desulfurization vessel 102. Through the gas outlet 27, the processed gas can flow out of the lower half 1a of the pressure vessel 1, which functions as a second desulfurization vessel 103.

In the embodiment of figures 4 to 6, the partition wall 7 is provided with openings 28, which can be best seen in figure 8. The openings 28 establish fluid communication between the upper half 1b and the lower half 1a of the pressure vessel 1. The gas can thus flow from the first desulfurization vessel 102 into the second desulfurization vessel 103 inside the pressure vessel 1, which reduces the external piping needed for the desulfurization arrangement. The pressure inside the upper half 1b and the lower half 1a of the pressure vessel 1 is substantially the same, and the partition wall 7 does therefore not need to carry significant forces. As in the embodiment of figures 1 to 3, the partition wall 7 comprises a first wall element 7a covering the upper end of the lower half 1a of the pressure vessel 1 and a second wall element 7b covering the lower end of the upper half 1b of the pressure vessel 1. The first wall element 7a is attached to the lower half 1a of the pressure vessel 1 and the second wall element 7b is attached to the upper half 1b of the pressure vessel 1. The wall elements 7a, 7b can be attached to the flanges 3, 4 of the lower half 1a and the upper half 1b of the pressure vessel 1 in a similar way as in the embodiment of figures 1 to 3.

An upper portion of the upper half 1b of the pressure vessel 1 is provided with a partition element 29, which separates an upper end portion 30 from the rest of the pressure vessel 1. The partition element 29 is provided with openings for establishing fluid communication between the upper end portion 30 and the rest of the upper half 1b of the pressure vessel 1. In the embodiment of the figures, the partition element 29 is a net. The upper end portion 30 is filled with

alumina balls. The gas inlet 20 opens to the upper end portion 30. The rest of the upper half 1b of the pressure vessel is filled with an absorbent that removes sulfur compounds from the gas that is introduced into the pressure vessel 1.

- 5 The construction of the lower half 1a of the pressure vessel 1 is similar. A lower portion of the lower half 1a is provided with a partition element 33, which separates a lower end portion 34 from the rest of the lower half 1a of the pressure vessel 1. The lower end portion 34 is filled with alumina balls. The rest of the lower half 1a of the pressure vessel 1 is filled with the absorbent. The gas
10 outlet 27 opens to the lower end portion 34.

The pressure vessel 1 of figures 4 to 6 provides the same benefits as the pressure vessel 1 of figures 1 to 3. The footprint of the pressure vessel 1 is smaller than the footprint of two separate pressure vessels, the pressure vessel 1 is easy to fill and it can be transported in two parts for servicing and exchange of
15 the absorbent material.

It will be appreciated by a person skilled in the art that the invention is not limited to the embodiments described above, but may vary within the scope of the appended claims.

Claims

1. A pressure vessel (1) for processing gas that contains hydrocarbons for use as a fuel in an internal combustion engine (100), the pressure vessel (1) comprising a gas inlet (20) that is located in an upper portion of the pressure
5 vessel (1) when the pressure vessel (1) is in the intended operating position, and a gas outlet (27) that is located in a lower portion of the pressure vessel (1) when the pressure vessel (1) is in the intended operating position, wherein the pressure vessel (1) comprises a lower half (1a) and an upper half (1b), the upper half (1b) being removably attached to the lower half (1a), the gas inlet
10 (20) is arranged in the upper half (1b) of the pressure vessel (1), the gas outlet (27) is arranged in the lower half (1a) of the pressure vessel (1), and the pressure vessel (1) comprises a partition wall (7) that is arranged between the lower half (1a) and the upper half (1b).
2. A pressure vessel (1) according to claim 1, wherein the partition wall (7)
15 comprises a first wall element (7a) that is attached to the lower half (1a) of the pressure vessel (1) and a second wall element (7b) that is attached to the upper half (1b) of the pressure vessel (1).
3. A pressure vessel (1) according to claim 1 or 2, wherein the partition wall (7) comprises a plurality of openings (28) for establishing fluid communication
20 between the upper half (1b) and the lower half (1a) of the pressure vessel (1).
4. A pressure vessel (1) according to any of claims 1 to 3, wherein the upper end of the lower half (1a) of the pressure vessel (1) is provided with a first flange (3) and the lower end of the upper half (1b) of the pressure vessel (1) is provided with a second flange (4) that is configured to be attached to the first
25 flange (3).
5. A pressure vessel (1) according to any of the preceding claims, wherein an upper portion of the upper half (1b) is provided with a first gas inlet (20), an upper portion of the lower half (1a) is provided with a second gas inlet (21), a lower portion of the upper half (1b) is provided with a first gas outlet (26), and a
30 lower portion of the lower half (1a) is provided with a second gas outlet (27).
6. A pressure vessel (1) according to any of the preceding claims, wherein a lower portion of the lower half (1a) of the pressure vessel (1) is provided with a partition element (33) that is horizontal in the intended operating position of the

pressure vessel (1) and separates a lower end portion (34) from the rest of the pressure vessel (1), the partition element (33) comprising a plurality of openings for establishing fluid communication between the lower end portion (34) and the rest of the pressure vessel (1) and the gas outlet (27) opening to the lower end portion (34).

7. A pressure vessel (1) according to any of the preceding claims, wherein an upper portion of the upper half (1b) of the pressure vessel (1) is provided with a partition element (29) that is horizontal in the intended operating position of the pressure vessel (1) and separates an upper end portion (30) from the rest of the pressure vessel (1), the partition element (29) comprising a plurality of openings for establishing fluid communication between the upper end portion (30) and the rest of the pressure vessel (1) and the gas inlet (20) opening to the upper end portion (30).

8. A pressure vessel (1) according to any of the preceding claims, wherein one of the upper half (1b) and the lower half (1a) of the pressure vessel (1) is configured to work as a reformer (104) and the other is configured to work as a methanator (117).

9. A pressure vessel (1) according to any of claims 1 to 8, wherein each of the upper half (1b) and the lower half (1a) of the pressure vessel (1) is configured to work as a desulphurization vessel (102, 103).

10. A power generating system comprising an internal combustion engine (100) that can be operated using a gaseous fuel and a first vessel (102, 104) and a second vessel (103, 117) for processing the gas to be used in the internal combustion engine (100), wherein the first vessel (102, 104) and the second vessel (103, 117) are integrated into a pressure vessel (1) according to any of the preceding claims.

11. A power generating system according to claim 10, wherein the first vessel is a reformer (104) and the second vessel is a methanator (117).

12. A power generating system according to claim 10, wherein the first vessel and the second vessel are desulfurization vessels (102, 103).

1/4

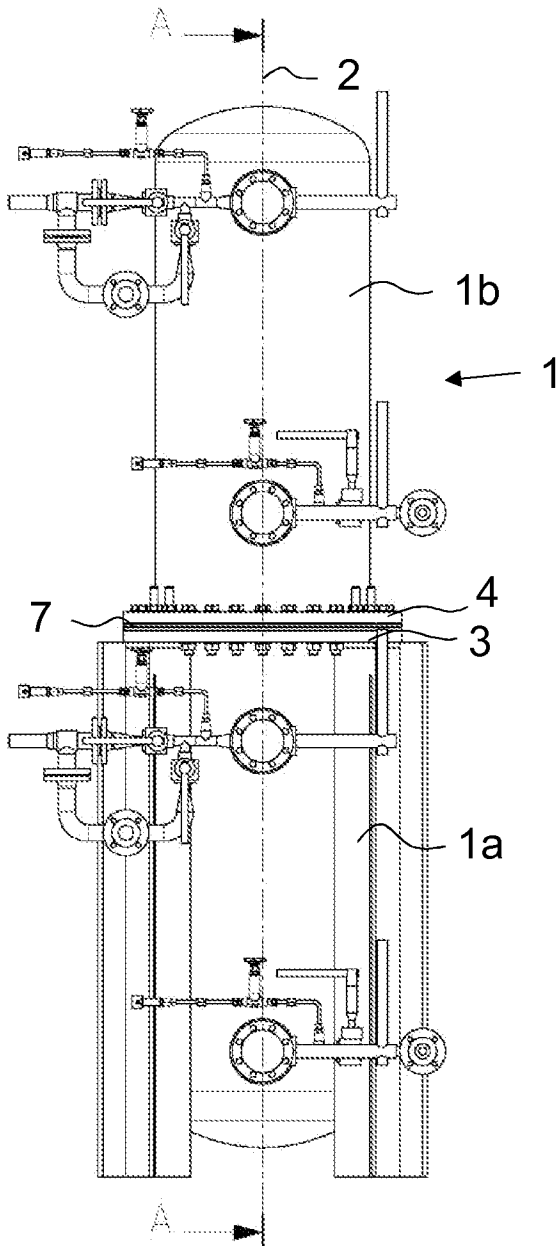


FIG. 1

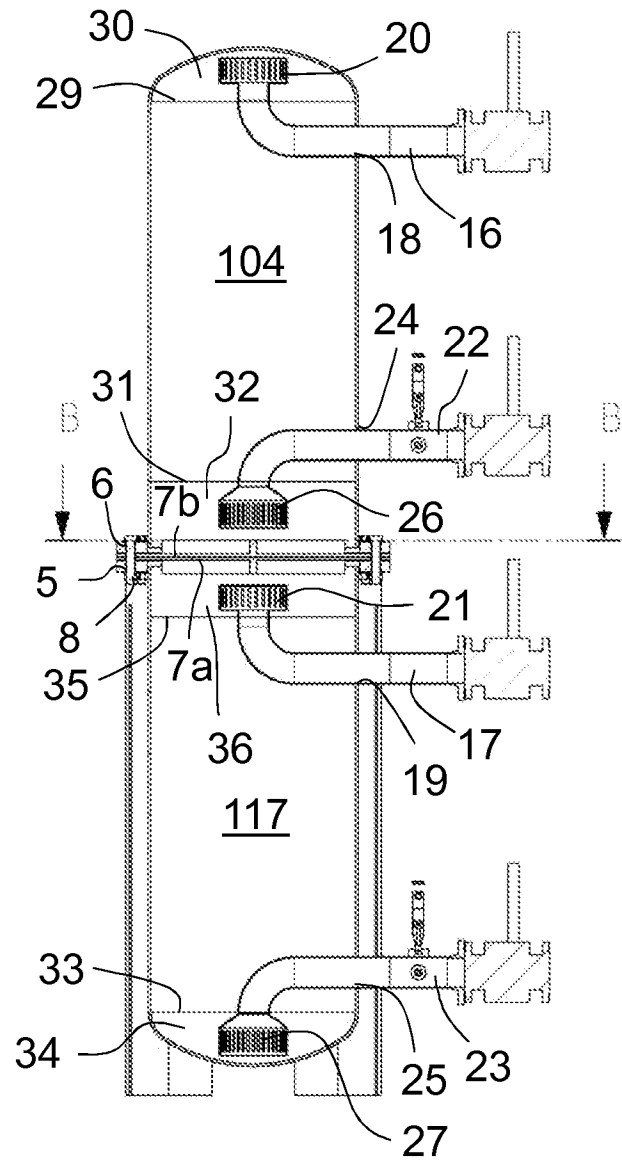


FIG. 2

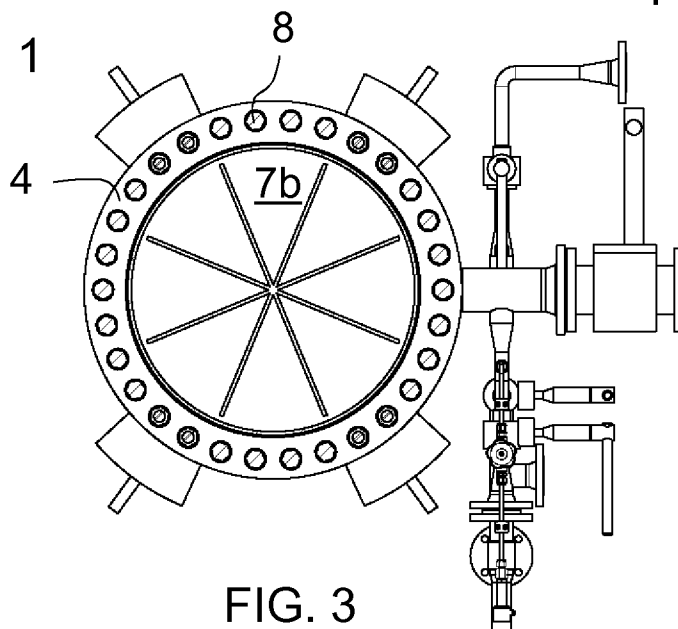


FIG. 3

2/4

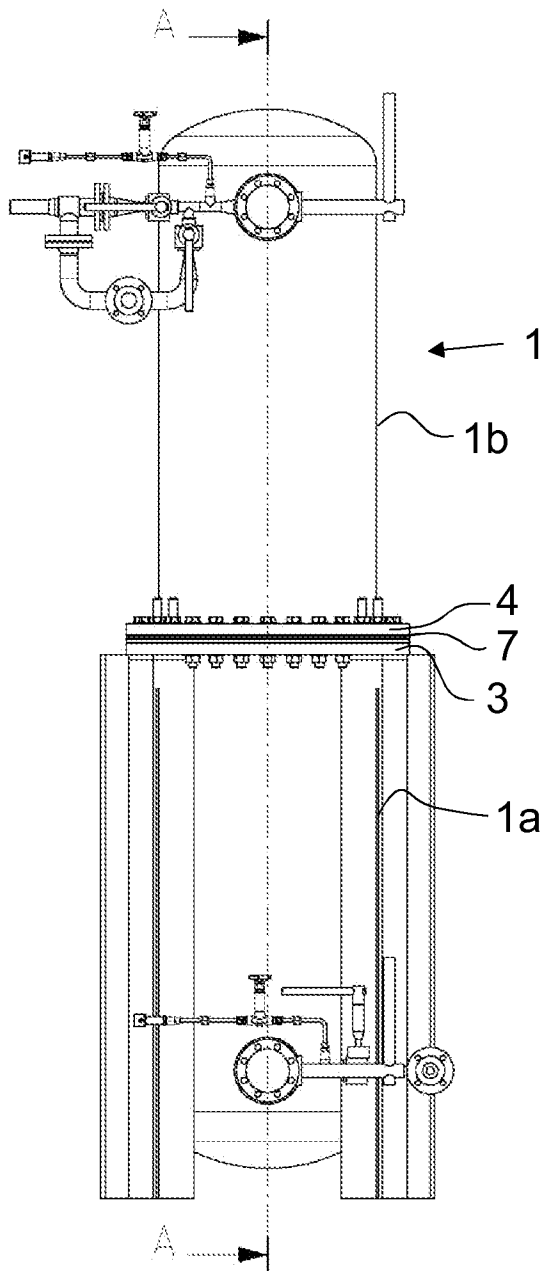


FIG. 4

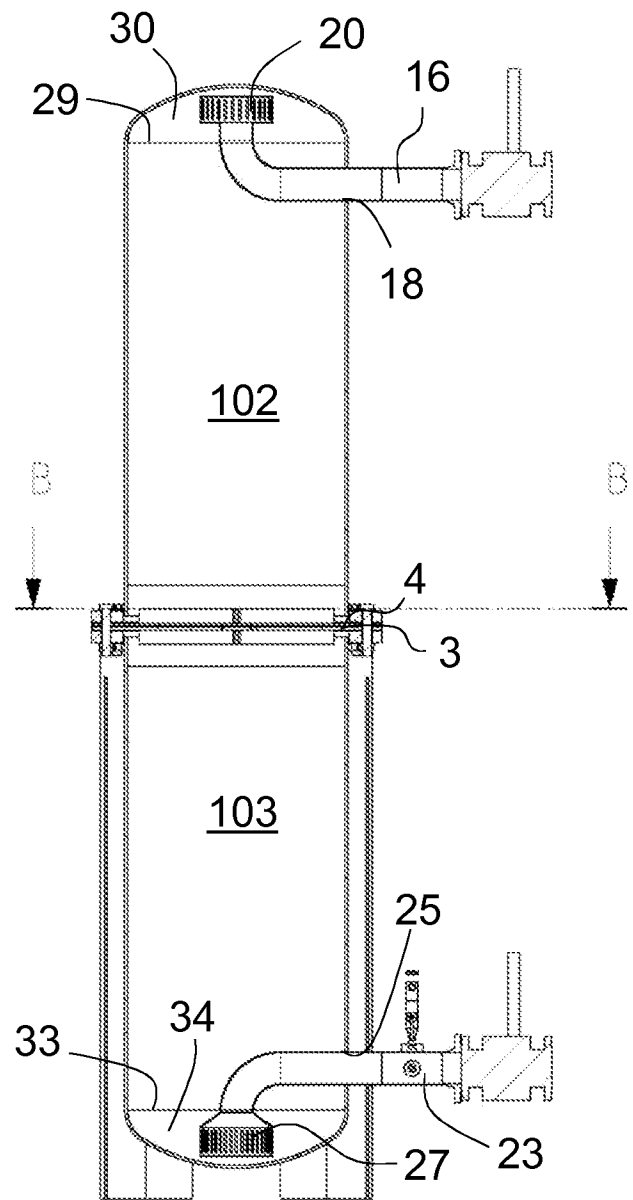


FIG. 5

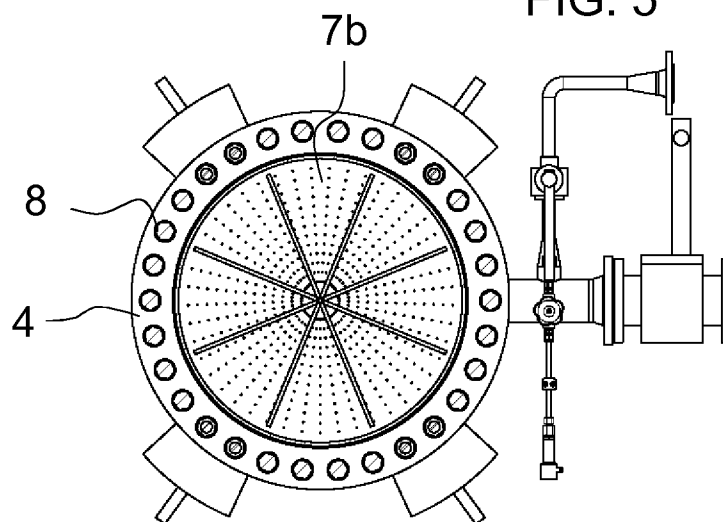


FIG. 6

3/4

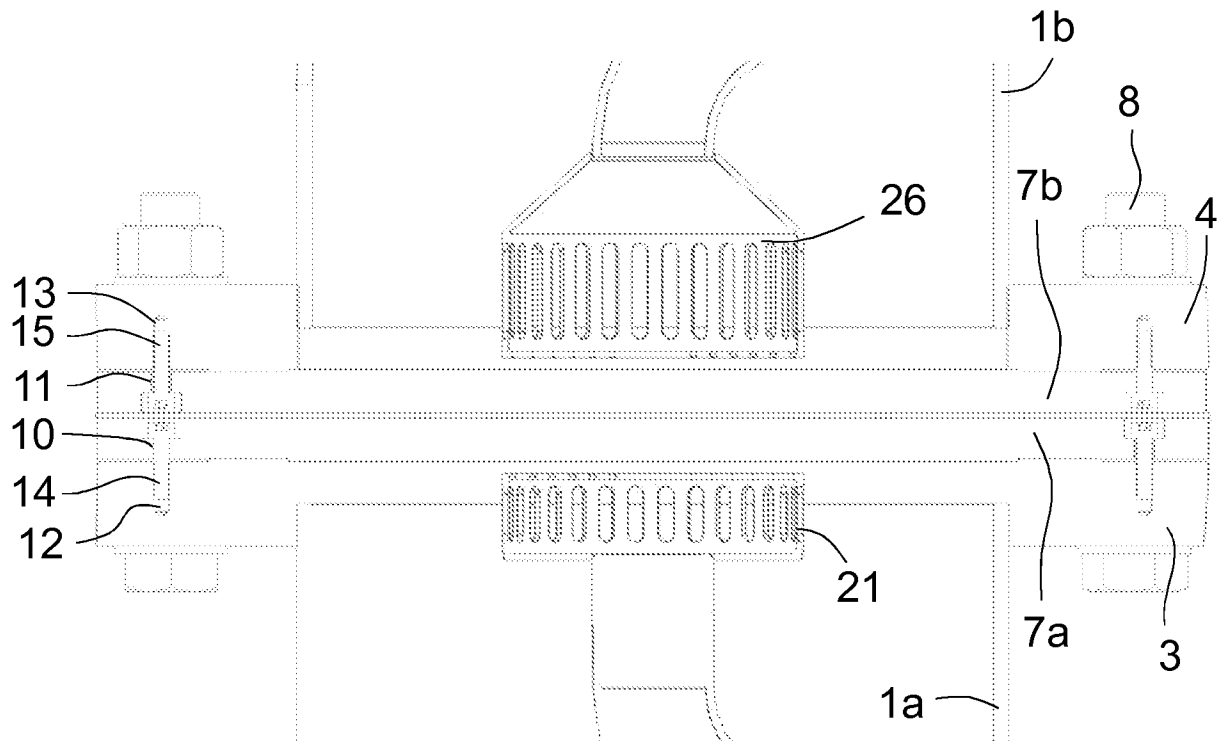


FIG. 7

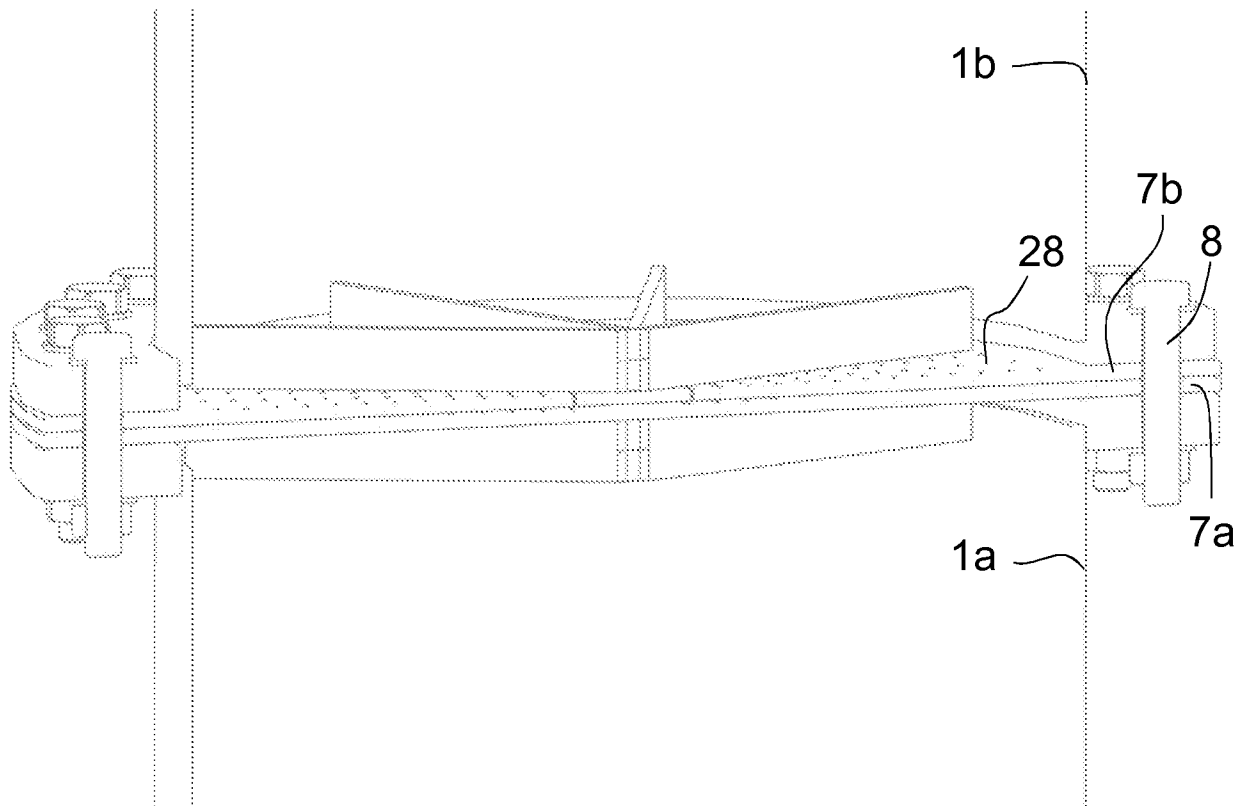


FIG. 8

4/4

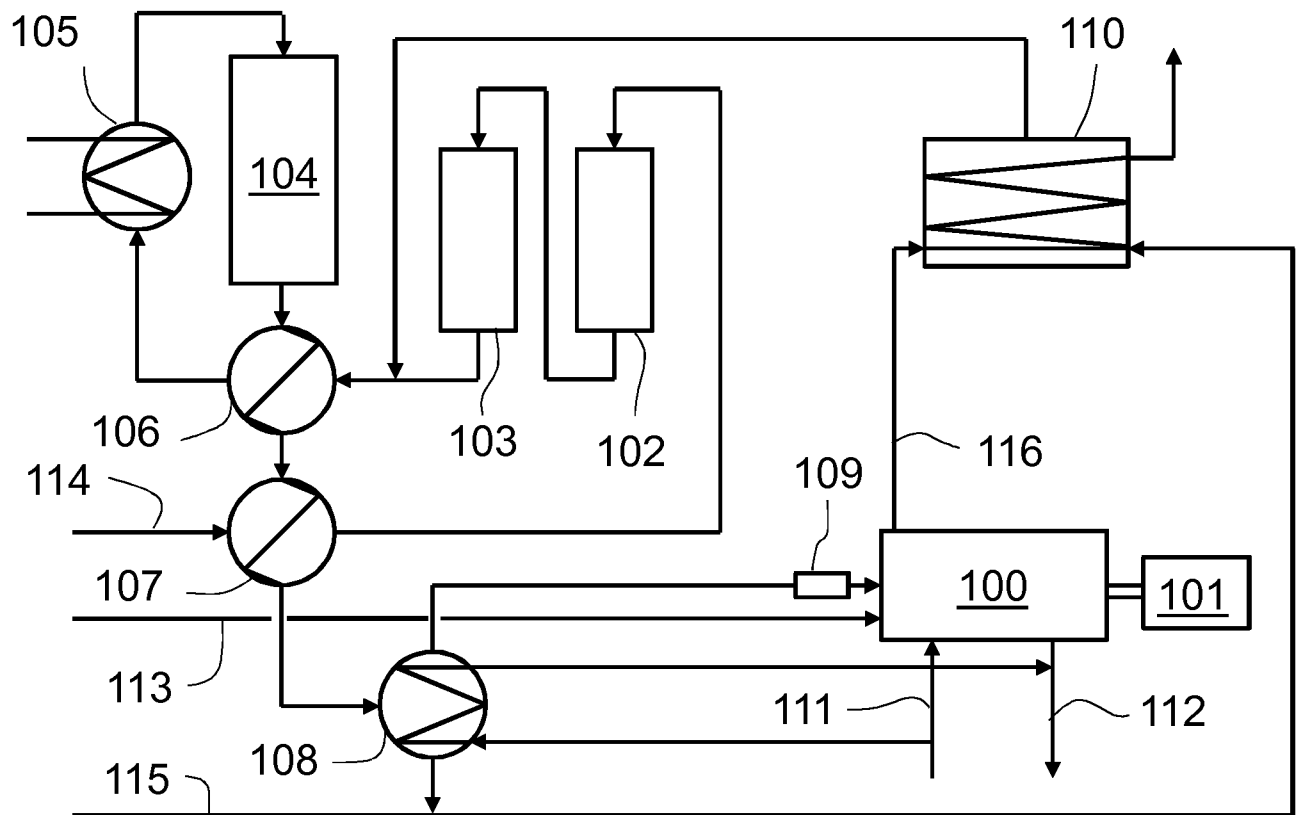


FIG. 9

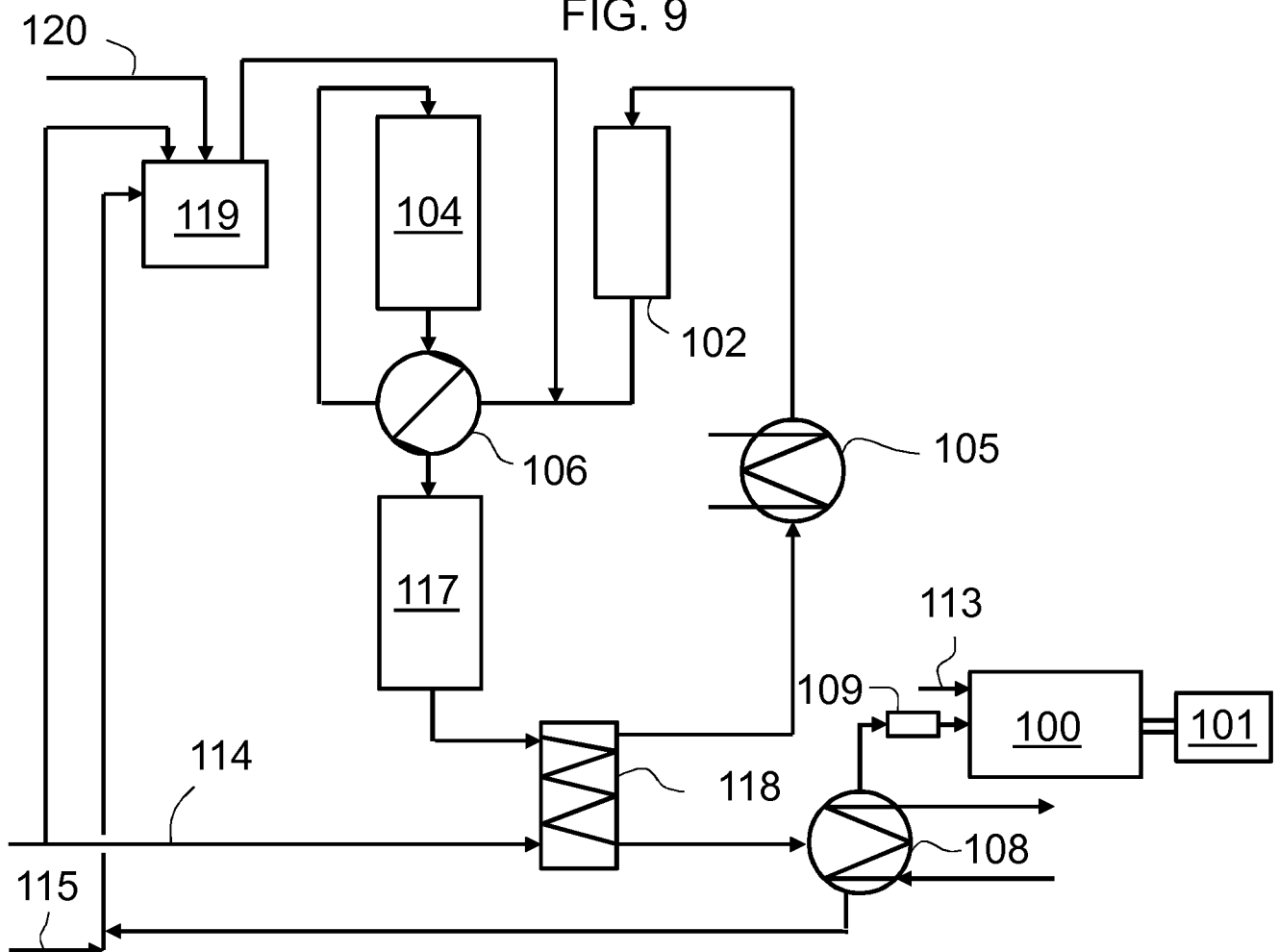


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2015/050679

A. CLASSIFICATION OF SUBJECT MATTER

INV. C10L3/10 F25J3/04 F02C3/22 F02M21/02 C10L3/08
B01J3/04 B01J8/00

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)

C10L F25J F02C F02M F17C B01J

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)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/181079 A1 (JOHNSON MATTHEY PLC [GB]) 13 November 2014 (2014-11-13) claims 1-4; figures 1,2 page 10, line 5 - page 11, line 31 -----	1-12
X	US 8 173 082 B1 (WANGEROW JAMES [US] ET AL) 8 May 2012 (2012-05-08) claims 1-13; figures 2,3 column 4, line 41 - column 5, line 44 -----	1-12
X	CN 101 982 448 A (NAT INST CLEAN & LOW CARBON ENERGY) 2 March 2011 (2011-03-02) paragraphs [0063] - [0066]; figures 3,4 -----	1-12
X	US 2010/121126 A1 (NORTHROP PAUL S [US] ET AL) 13 May 2010 (2010-05-13) paragraphs [0037], [0040]; claims 1-21; figures 6-8 -----	1-12



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

22 June 2016

Date of mailing of the international search report

13/07/2016

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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			WO 2014181079 A1	13-11-2014

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			WO 2008156524 A1	24-12-2008
