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(11) **EP 2 916 075 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
09.09.2015 Bulletin 2015/37

(51) Int Cl.:
F23K 5/10 *(2006.01)*

(21) Application number: **14157773.4**

(22) Date of filing: **05.03.2014**

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

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(54) **Method and system for supplying a fuel into a combustion chamber**

(57) The method for supplying a fuel into a combustion chamber (1) comprises mixing the fuel with supercritical pressure CO_2 forming a mixture and injecting the mixture into a combustion chamber (1) having a pressure lower than the CO_2 critical pressure.

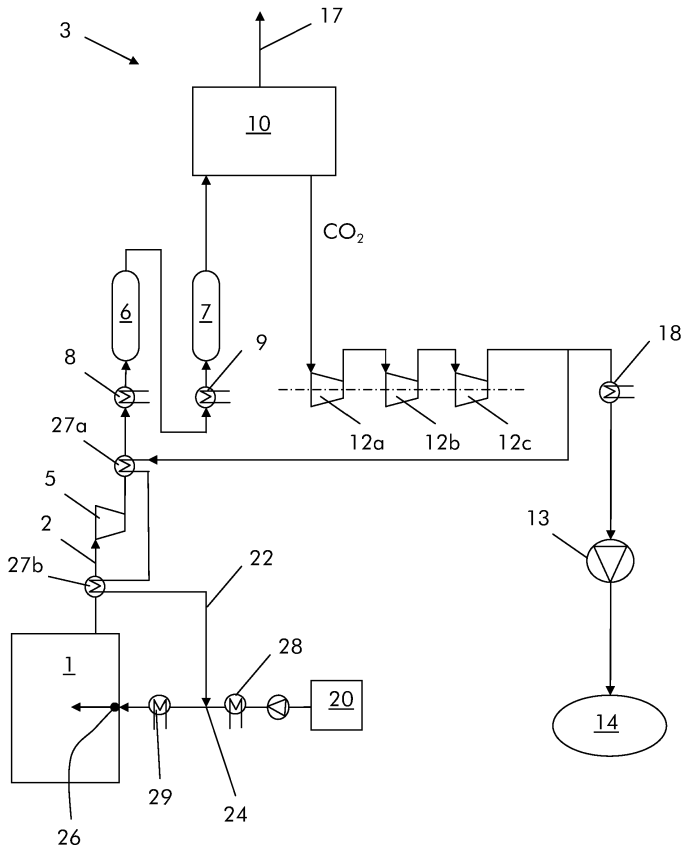

Fig. 1

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Description

TECHNICAL FIELD

[0001] The present invention relates to a method and system for supplying a fuel into a combustion chamber. The combustion chamber is for example the combustion chamber of a boiler or furnace for industrial applications. The combustion chamber can be an oxy fuel combustion chamber, i.e. a combustion chamber that is supplied with a fuel and substantially pure oxygen, this is anyhow not needed and the combustion chamber can be supplied with a fuel and air. In addition, the combustion chamber can also be supplied with recirculated flue gas, but this is also not mandatory.

[0002] The fuel is a high viscosity fluid, i.e. a fluid that alone is not able to pass through the ducts and injectors of the combustion chamber, but needs appropriate helps for this. For example the fuel is heavy residue.

BACKGROUND

[0003] Crude oil undergoes a number of treatments in order to separate different products from it, such as for example, liquefied petroleum gas, gasoline, diesel oil, kerosene, etc.; the remaining of these treatments is the so called heavy residue, that is a high viscosity product that at atmospheric conditions becomes solid.

[0004] Traditionally, heavy residue is used in boilers as a fuel, for example in power plants.

[0005] In order to get a product that can be handled, such as for example injected and atomized through injectors into the combustion chamber of a boiler, the heavy residue is heated and mixed with kerosene and/or water in order to obtain a low viscosity fluid.

[0006] This known solution has some disadvantages.

[0007] Heavy residue must be heated up to a temperature very close to its coking temperature. At the coking temperature, the heavy residue forms solid coke deposits that accumulate in piping and injectors, blocking them. The coking temperature for the heavy residue can begin already at temperatures as low as 200-250°C depending on the originating crude feedstock. When the heavy residue is heated up close to the coking temperature, there is the risk that some fractions of the heavy residue start to coke due to an uneven mixture of the heavy residue.

[0008] In addition, the known solution requires the use of highly expensive fuel, such as kerosene, or high expensive fluid, such as water (in some countries water can be more expensive than oil).

SUMMARY

[0009] An aspect of the invention includes providing a method and system that avoid heating of the heavy residue or require a heating up to a temperature well far apart from the coking temperature, such that cocking is prevented.

[0010] Another aspect of the invention includes providing a method and system that avoid or at least limit the use of expensive fuel (such as kerosene) or fluid (such as water) together with the heavy residue.

[0011] These and further aspects are attained by providing a method and a system in accordance with the accompanying claims.

[0012] The described solution addresses heavy residue being fuels that have a viscosity of more than 150 cSt at a temperature of 100°C.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Further characteristics and advantages will be more apparent from the description of a preferred but non-exclusive embodiment of the method and system, illustrated by way of non-limiting example in the accompanying drawings, in which:

Figure 1 shows an example of the system in a first embodiment;
Figure 2 shows an example of the system in a second embodiment;
Figure 3 shows an example of the system in a third embodiment;
Figure 4 shows an example of the system in a fourth embodiment;
Figure 5 shows an example of injection, and
Figure 6 shows a nozzle.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0014] In the following the system for supplying a fuel such as heavy residue (i.e. a fuel having a viscosity equal to or greater than 150 cSt at a temperature of 100°C) into a combustion chamber 1 is described first.

[0015] The combustion chamber is a part of a boiler for a power plant or an industrial furnace.

[0016] The combustion chamber 1 combusts a fuel and generates flue gas 2 that is supplied to a flue gas treatment system 3.

[0017] The flue gas treatment system 3 can be of any kind and, for example, it can include a compressor 5, a mercury removal unit 6 and a drier 7. Heat exchangers 8, 9 are preferably provided upstream of the mercury removal unit 6 and drier 7.

[0018] From the drier 7 the flue gas is supplied into a separation unit 10, where the CO_2 is separated from other gas. The CO_2 is thus supplied to a compressor 12a-c (for example a multi stage, intercooled compressor) where it is compressed up to or above the supercritical pressure, and then to a pump 13 (but this pump is not needed and it is used according to the design) to be further compressed for storage at 14.

[0019] The separation unit 10 can be of any type, for example figure 2 shows a scheme in which the separation unit includes two stages 15a, 15b of condensation by

cooling. In this example CO_2 that condenses 16a, 16b at each condensation stage 15a, 15b is also used as cooling medium. Likewise, gas 17 being the flue gas deprived of CO_2 is expanded and used as cooling medium at the condensation stages 15a, 15b; the gas 17 is then vented.

[0020] Between the compressor 12a-c and the pump 13 or storage 14 a heat exchanger 18 can be provided (it is not mandatory and is provided according to the specific design). The heat exchanger 18 is used for cooling the CO_2 compressed at the compressor 12a-c.

[0021] The system 1 comprises a fuel supply 20, a supercritical pressure CO_2 supply 22, a mixing system 24 for forming a mixture of fuel and supercritical pressure CO_2, injectors 26 connected to the mixing system 24 for injecting the mixture into the combustion chamber 1.

[0022] The mixing system can be defined by the converging pipes through which supercritical pressure CO_2 and fuel pass through, or by a dedicated mixer or tank.

[0023] Advantageously the combustion chamber has a pressure lower than the CO_2 critical pressure.

[0024] In addition, the system preferably has (but this is not needed and depends on the particular design and conditions) at least a heat exchanger for heating the mixture and/or the fuel and/or the supercritical pressure CO_2.

[0025] The heat exchangers can include:

- the heat exchangers 27a, 27b that allow heating of the supercritical pressure CO_2 before it is mixed with the fuel; in different embodiments both the heat exchangers 27a and 27b can be provided, or only one of them can be provided, or none of them can be provided;
- the heat exchanger 28 that allows heating of the fuel before it is mixed with the supercritical pressure CO_2; in different examples it can be provided or not;
- the heat exchanger 29 that allows heating of the mixture of fuel and supercritical pressure CO_2; in different examples it can be provided or not.

[0026] Naturally, all or none of the heat exchangers 27a, 27b, 28, 29 can be provided, in addition any combination of heat exchangers 27a, 27b, 28, 29 is possible.

[0027] The supercritical pressure CO_2 can be supplied from the line that forwards the CO_2 to the storage 14, from a position upstream the pump 13 or downstream the pump 13. For example the supercritical pressure CO_2 supply 22 can depart from a position between the compressor 12a-c and the heat exchanger 18 (figures 1 and 2) and/or from a position between heat exchanger 18 and the pump 13 and/or from a position between the pump 13 and the storage 14 (figure 14).

[0028] The operation of the system is apparent from that described and illustrated and is substantially the following.

[0029] At the combustion chamber 1 flue gas 2 is generated from the combustion of the fuel. The flue gas is compressed at the compressor 5 and then the flue gas undergoes cooling at the heat exchanger 8, mercury removal at the mercury removal unit 6, cooling at the heat exchanger 9, water removal at the drier 7. Thus the flue gas is supplied into the separation unit 10 where CO_2 is separated from the other gas 17 (such as nitrogen, argon, etc.). The gas 17 is vented into the atmosphere and the CO_2 (that is still gas) is supplied to the compressor 12a-c (usually a multistage, intercooled compressor that is used to prepare the CO_2 for storage).

[0030] At the compressor 12a-c the CO_2 is compressed up to or above the critical pressure (critical pressure 72.9 bar or 7.39 MPa); then at the heat exchanger 18 the CO_2 compressed at or above the critical pressure is cooled.

[0031] Depending on the availability of cooling media and specific design, the CO_2 can be either:

- compressed at the compressor 12a-c at or above the critical pressure and then condensed at the heat exchanger 18; the condensed CO_2 at a pressure above the critical pressure is then pumped via the pump 13,
- compressed to the final pressure at the compressor 12a-c; the final pressure is usually about 100 bar (in this case the pump 13 is not needed), cooling after compression at the heat exchanger 18 is possible at a temperature above or below the critical pressure,
- compressed at the compressor 12a-c at or above the critical pressure and cooled to a temperature below the critical temperature at the heat exchanger 18; the compressed CO_2 is then pumped via the pump 13,
- compressed at the compressor 12a-c at or above the critical pressure, no cooling is provided in this case or cooling at the heat exchanger 18 to a temperature above the critical temperature, such that the CO_2 is in supercritical state.

[0032] Naturally also other combinations of compression and cooling are possible.

[0033] The supercritical CO_2, i.e. CO_2 at or above the critical pressure and at or above the critical temperature (304.25 K) has a high density and can thus be pumped.

[0034] Likewise, the CO_2 at or above the critical pressure and below the critical temperature (304.25 K) has a high density and can be pumped. This region is sometimes called the dense phase region.

[0035] At the pump 13 the supercritical CO_2 or CO_2 in the dense phase region is further compressed for storage. Downstream the pump 13 the pressure of the supercritical CO_2 is 100 bar or more.

[0036] Supercritical pressure CO_2 (the temperature of the supercritical pressure CO_2 can be the supercritical temperature, or it can be above or below the supercritical temperature) is thus preferably supplied from a position downstream the compressor 12a-c and upstream or downstream the pump 13 (when provided) to the mixing system 24. Likewise, heavy residue is supplied from the

fuel supply 20 to the mixing system 24. At the mixing system 24 the heavy residue and supercritical pressure CO_2 form a mixture.

[0037] The supercritical pressure CO_2 is a very good solvent for heavy residue. For this reason, the mixture of heavy residue and supercritical pressure CO_2 can contain a large amount of CO_2, such that the viscosity of the mixture allows injection in the combustion chamber 1.

[0038] In addition, in order to adjust the viscosity, the mixture (the temperature of the mixture after mixing is typically below 60°C) can be heated at the heat exchanger 29. Alternatively or in addition to the heating at the heat exchanger 29, also the supercritical pressure CO_2 and/or the heavy residue can be heated at the heat exchangers 27a, 27b, 28, in such a way that that the temperature of the mixture containing the heavy residue and the supercritical pressure CO_2 falls in the preferred temperature range.

[0039] The preferred range for the temperature of the mixture is between 50-160°C, with a more preferred range between 60-90°C; the temperature is thus well below the cocking temperature for the heavy residue.

[0040] From the mixing system 24 the mixture is supplied to the injectors 26 and is injected into the combustion chamber 1.

[0041] Advantageously, after the injection in the combustion chamber 1, the pressure of the mixture (containing supercritical pressure CO_2 and heavy residue) suddenly drops. The pressure drop causes a sudden expansion of the CO_2 (up to 10 times or more). Since the CO_2 is mixed with the heavy residue, this expansion helps atomization of heavy residue and its dispersion through the combustion chamber 1. Atomization and dispersion through the combustion chamber 1 help a complete and clean combustion.

[0042] Figure 5 shows the injectors 26 with nozzles 30, jets of mixtures 31 and the expanding CO_2 that promotes heavy residue dispersion through the combustion chamber 1 and atomization.

[0043] The fuel such as heavy residue atomized and dispersed through the combustion chamber can thus combust with air or oxygen.

[0044] Figure 6 shows an example of the nozzle 30; in this figure the arrow indicates the flow through the nozzle 30. In addition figure 6 shows the convergent-divergent design of the nozzle 30 that helps preventing excessive erosion.

[0045] The present invention also refers to a method for supplying a fuel into a combustion chamber.

[0046] The method comprises mixing the fuel with supercritical pressure CO_2 forming a mixture and injecting the mixture into a combustion chamber having a pressure lower than the CO_2 critical pressure.

[0047] The mixture contains between 10-70% by weight of supercritical pressure CO_2 and preferably between 15-25% by weight of supercritical pressure CO_2.

[0048] The mixture and/or the fuel and/or the supercritical pressure CO_2 can be heated in order to obtain a heated mixture, whose viscosity is preferably between 15-30 centipoise. This viscosity allows easy injection of the heavy residue through the injector 26.

[0049] The temperature of the heated mixture is between 50-160°C and preferably between 60-90°C.

[0050] The mixture and/or the fuel and/or the supercritical pressure CO_2 are heated by cooling the flue gas.

[0051] Naturally the features described may be independently provided from one another.

[0052] In practice the materials used and the dimensions can be chosen at will according to requirements and to the state of the art.

REFERENCE NUMBERS

[0053]

1	combustion chamber
2	flue gas
3	flue gas treatment system
5	compressor
6	mercury removal unit
7	dryer
8	heat exchanger
9	heat exchanger
10	separation unit
12a-c	compressor
13	pump
14	storage
15a, b	stage of condensation
16a, b	condensed CO_2
17	gas
18	heat exchanger
20	fuel supply
22	supercritical pressure CO_2 supply
24	mixing system
26	injector
27a, b	heat exchanger

28 heat exchanger

29 heat exchanger

30 nozzle

31 jet of mixture

32 CO_2

Claims

1. A method for supplying a fuel into a combustion chamber (1), **characterised by**
mixing the fuel with supercritical pressure CO_2 forming a mixture,
injecting the mixture into a combustion chamber (1) having a pressure lower than the CO_2 critical pressure.

2. The method of claim 1, **characterised in that** the supercritical pressure CO_2 contained in the mixture is in the supercritical state.

3. The method of claim 1, **characterised in that** the mixture contains between 10-70% by weight of supercritical pressure CO_2.

4. The method of claim 1, **characterised in that** the mixture contains between 15-25% by weight of supercritical pressure CO_2.

5. The method of claim 1, **characterised by** heating the mixture and/or the fuel and/or the supercritical pressure CO_2 in order to obtain a heated mixture.

6. The method of claim 5, **characterised in that** the mixture and/or the fuel and/or the supercritical pressure CO_2 are heated in order to obtain a heated mixture with a viscosity between 15-30 centipoise.

7. The method of claim 5, **characterised in that** the temperature of the heated mixture is between 50-160°C.

8. The method of claim 5, **characterised in that** the temperature of the heated mixture is between 60-90°C.

9. The method of claim 5, **characterised in that** flue gas (2) is discharged from the combustion chamber (1), wherein the mixture and/or the fuel and/or the supercritical pressure CO_2 are heated by cooling the flue gas.

10. The method of claim 1, **characterised in that** the fuel has a viscosity equal to or greater than 150 cSt at a temperature of 100°C.

11. A system for supplying a fuel into a combustion chamber (1), **characterised by** comprising
a fuel supply (20),
a supercritical pressure CO_2 supply (22),
a mixing system (24) for forming a mixture of fuel and supercritical pressure CO_2,
at least an injector (26) connected to the mixing system (24), the at least an injector (26) for injecting the mixture into the combustion chamber (1),
the combustion chamber (1) having a pressure lower than the CO_2 critical pressure.

12. The system of claim 11, **characterised by** further comprising at least a heat exchanger (27a, 27b, 28, 29) for heating the mixture and/or the fuel and/or the supercritical pressure CO_2.

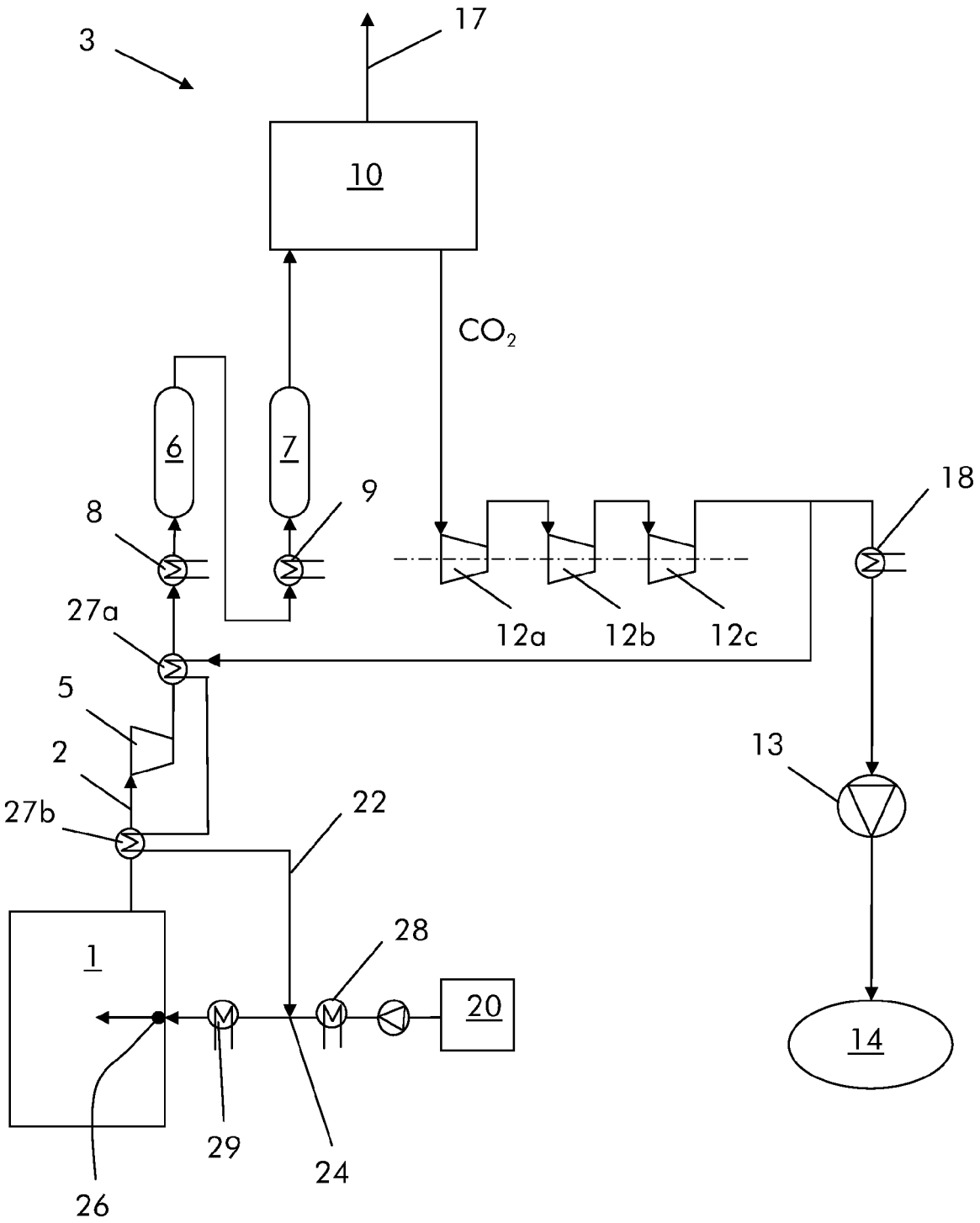
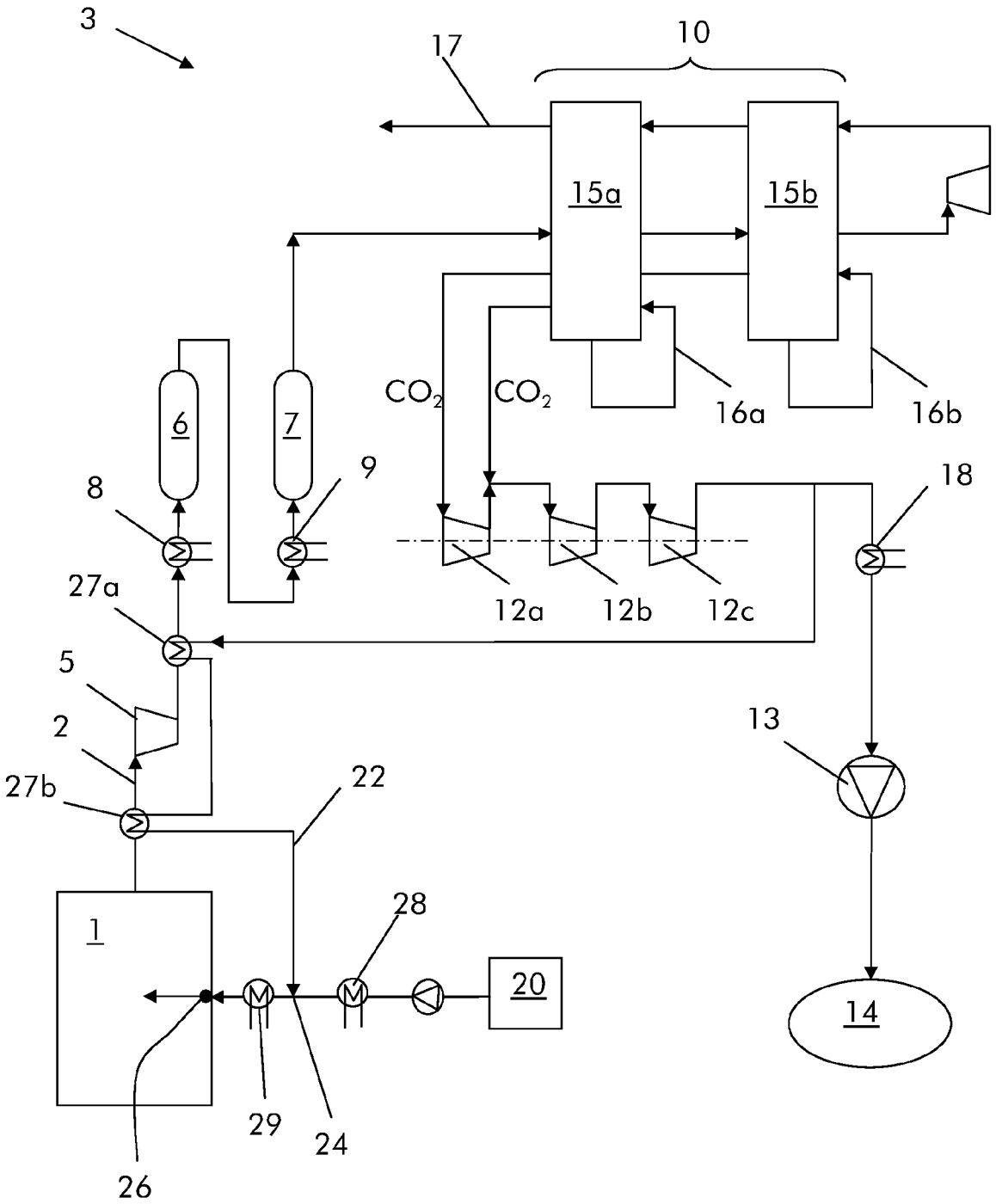


Fig. 1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17
10
15a
15b
CO_2
CO_2
16a
16b
6
7
8
9
18
12a
12b
12c
27a
5
2
27b
22
13
1
28
20
14
29
24
26

Fig. 2

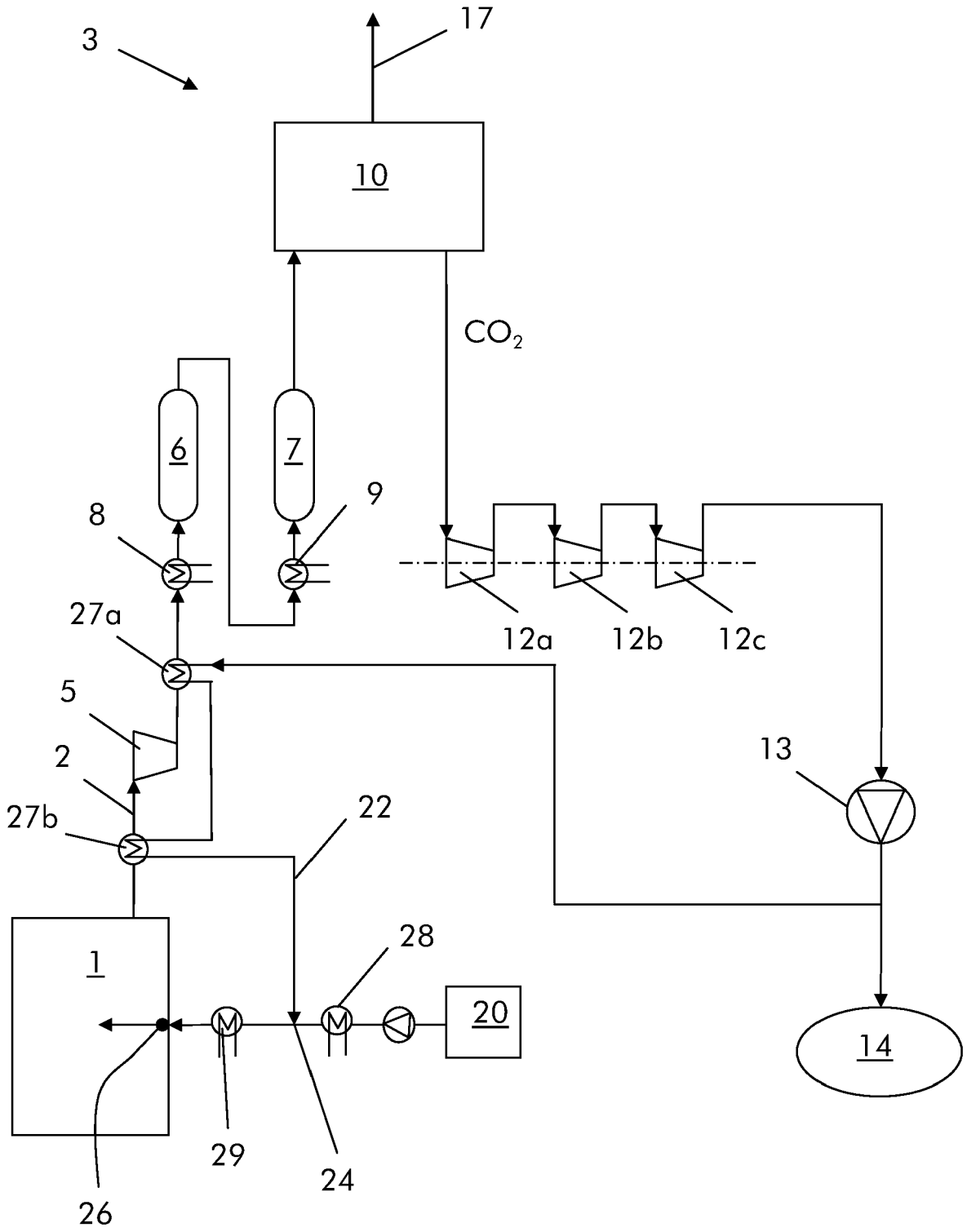

Fig. 3

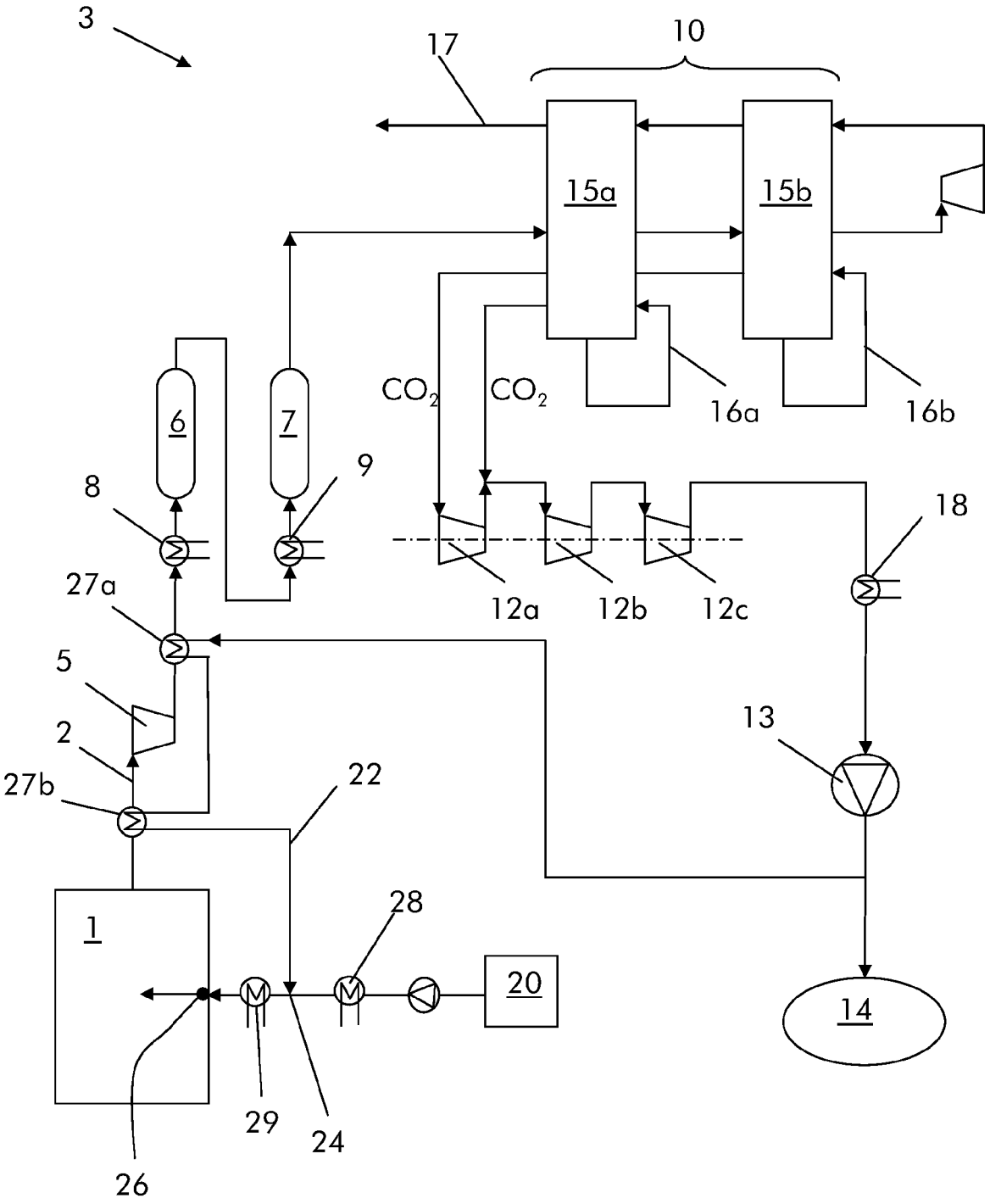
3
17
10
15a
15b
CO_2
CO_2
16a
16b
6
7
8
9
18
12a
12b
12c
27a
5
2
27b
22
13
1
28
20
14
29
24
26

Fig. 4

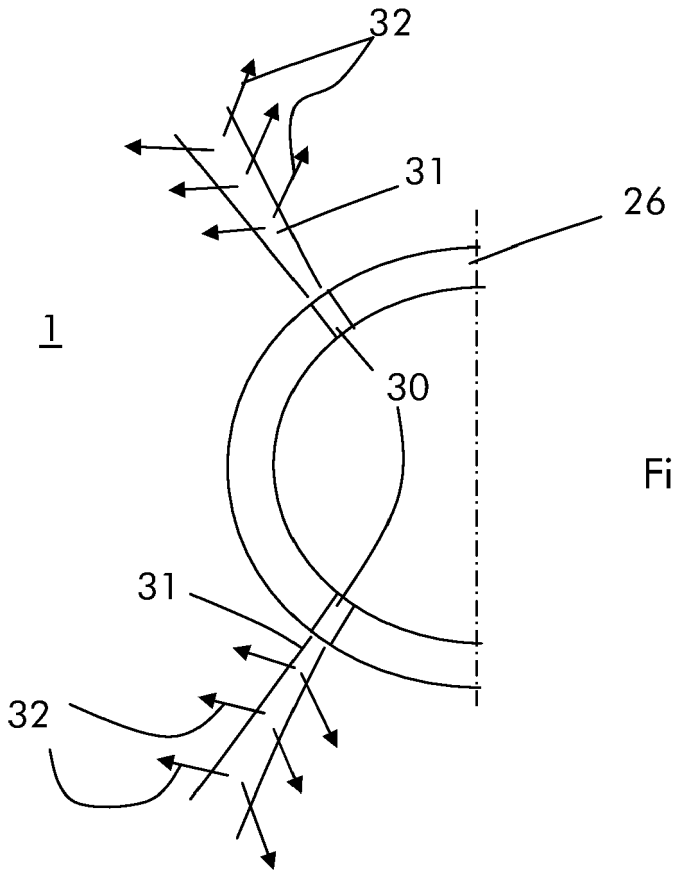

Fig. 5

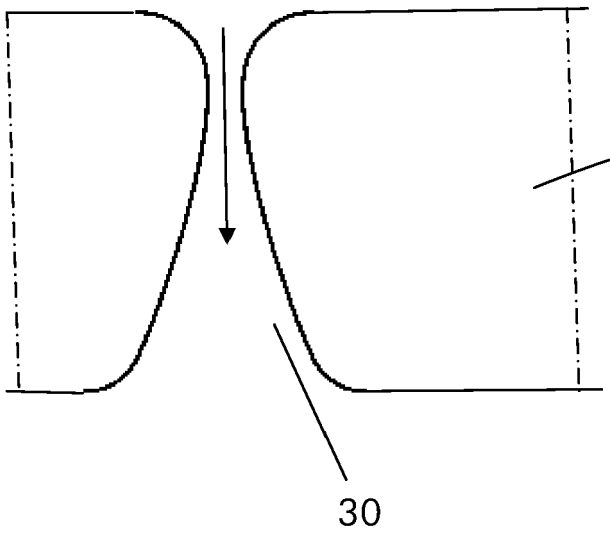

Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	14 August 2014	Mougey, Maurice

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EUROPEAN SEARCH REPORT

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