

(19)



(11)

**EP 4 571 224 A1**

(12)

**EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
**18.06.2025 Bulletin 2025/25**

(51) International Patent Classification (IPC):  
**F25J 1/00** (2006.01)

(21) Application number: **23307196.8**

(52) Cooperative Patent Classification (CPC):  
**F25J 1/0027; F25J 1/004; F25J 1/0052;  
F25J 1/0095; F25J 1/0221; F25J 1/0222;  
F25J 1/025; F25J 1/0264; F25J 2210/06;  
F25J 2210/62; F25J 2220/80; F25J 2220/82;  
F25J 2230/04; F25J 2230/30; F25J 2235/80**

(22) Date of filing: **13.12.2023**

(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 ME MK MT NL  
NO PL PT RO RS SE SI SK SM TR**  
Designated Extension States:  
**BA**  
Designated Validation States:  
**KH MA MD TN**

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**(54) A METHOD FOR CO2 COMPRESSION AND LIQUEFACTION**

(57) A method comprising:  
- obtaining a feed (12) comprising gaseous wet CO<sub>2</sub>,  
- compressing said feed to obtain a compressed feed (18),  
- liquefying the dehydrated feed to obtain a CO<sub>2</sub> rich liquid (14).

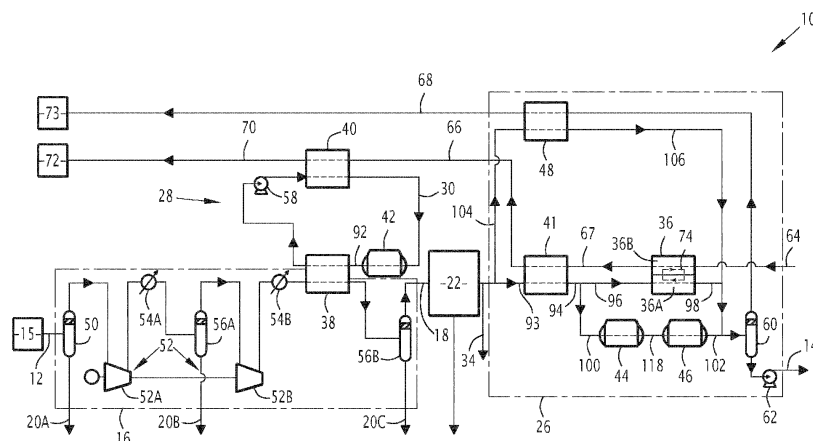
Liquefying comprises:

- performing a heat exchange between at least a first portion (96) of the dehydrated feed and a cold fluid (64) in a first heat exchanger (36) to obtain a first stream (98) of

CO<sub>2</sub> rich liquid and a partially heated gas (66),  
- obtaining the CO<sub>2</sub> rich liquid from at least the first stream,

Compressing said feed comprises:

- cooling the feed in a second heat exchanger (38) against a cooling stream (92) of a first refrigerant (30),  
- operating a first cooling cycle (28), in which the first refrigerant circulates and receives cold in a third heat exchanger (40) from the partially heated gas.

**FIG.1**

**Description****FIELD**

**[0001]** The present disclosure deals with a method for compressing and liquefying a feed of wet CO<sub>2</sub>.

**[0002]** The disclosure also deals with an installation adapted for performing such a method.

**BACKGROUND**

**[0003]** In known methods, CO<sub>2</sub> is usually recovered at low pressure, compressed, dehydrated and exported at very high pressure into export pipelines, or injected into depleted natural gas or oil wells.

**[0004]** Opportunities to export CO<sub>2</sub> in the liquid form are now emerging in the industry.

**[0005]** The specificities and behavior of CO<sub>2</sub> when liquefied are not as straightforward as often published in the literature. Many misconceptions can occur. This can lead to inefficient process, technical and mechanical issues, as well as large size equipment items. Many publications on this subject are often incomplete and misleading with regards to these aspects.

**[0006]** In general, CO<sub>2</sub> is compressed through a multi-stage compressor, dehydrated and then, if needed, liquefied. The liquefaction process is stand alone. An external refrigeration unit is required to cool and liquefy CO<sub>2</sub>. The refrigerant used is an industrial refrigerant, or sometimes ammonia.

**[0007]** However, such methods have a high energy demand. The refrigerant requires sourcing and import. As liquefaction is performed at the CO<sub>2</sub> export pressure, compression requires a lot of energy. The pieces of equipment needed to perform such methods are large, rated for high pressure, which leads to high investment costs.

**[0008]** An objective of the disclosure is to provide a method that partially or entirely overcomes the above drawbacks, in particular a method allowing to reduce the cost (CAPEX and OPEX) of producing liquefied CO<sub>2</sub>.

**SUMMARY OF THE DISCLOSURE**

**[0009]** To this end, the disclosure proposes a method comprising:

- obtaining a feed comprising gaseous CO<sub>2</sub>,
- compressing said feed in order to obtain a compressed feed and one or several streams of liquid, and
- liquefying the compressed feed in order to obtain a CO<sub>2</sub> rich liquid,

wherein liquefying comprises:

- performing a heat exchange between at least a first portion of the compressed feed and a cold fluid in a

first heat exchanger in order to obtain a first stream of CO<sub>2</sub> rich liquid and a partially heated gas, and obtaining the CO<sub>2</sub> rich liquid from at least the first stream of CO<sub>2</sub> rich liquid, wherein compressing said feed comprises:

- cooling the feed in a second heat exchanger, the feed receiving cold from a cooling stream of a first refrigerant, and
- operating a first cooling cycle, in which the first refrigerant circulates and receives cold in a third heat exchanger from the partially heated gas.

**[0010]** In other embodiments, the method may comprise one or several of the following features, taken in isolation or any technically feasible combination:

- said gaseous CO<sub>2</sub> is wet, the method comprising dehydrating the compressed feed prior to liquefying the compressed feed;
- the cold fluid is LNG;
- the first heat exchanger uses an intermediate fluid evaporating by heat exchange with said first portion of the compressed feed, and condensing by heat exchange with the cold fluid;
- the intermediate fluid comprises more than 90mol.% of ethane, ethylene, propane, propylene or ammonia;
- liquefying comprises precooling at least a first part of the compressed feed by heat exchange with the partially heated gas in a fourth heat exchanger in order to obtain a precooled CO<sub>2</sub> rich gas and to heat the partially heated gas, the first portion of the compressed feed admitted in the first heat exchanger being at least a part of the precooled CO<sub>2</sub> rich gas;
- liquefying comprises: cooling at least a second portion of the compressed feed by heat exchange with a second refrigerant in order to obtain a second stream of CO<sub>2</sub> rich liquid; operating a second cooling cycle in which the second refrigerant circulates; and obtaining the CO<sub>2</sub> rich liquid from at least the second stream of CO<sub>2</sub> rich liquid;
- the second refrigerant is a CO<sub>2</sub> rich fluid obtained from the compressed feed;
- operating the second cooling cycle includes expanding a stream of the second refrigerant in order to obtain a first cold stream of the second refrigerant and performing a heat exchange between the first cold stream and the first refrigerant in a fifth heat exchanger in order to obtain the cooling stream of the first refrigerant;
- operating the second cooling cycle includes: expanding a liquid stream of the second refrigerant in order to obtain a second cold stream of the second refrigerant; performing a heat exchange between the second cold stream and said part of the compressed feed in a sixth heat exchanger in order to obtain a cold CO<sub>2</sub> rich gaseous stream and a liquid stream of the second refrigerant; expanding the liquid stream

of the second refrigerant in order to obtain a third cold stream of the second refrigerant; and performing a heat exchange between the third cold stream and said gaseous stream in a seventh heat exchanger in order to obtain said second stream of CO<sub>2</sub> rich liquid;

- the first refrigerant comprises glycol;
- operating the first cooling cycle includes controlling a temperature of said cooling stream of the first refrigerant in order to prevent formation of CO<sub>2</sub> hydrates in the feed in the second heat exchanger;
- obtaining the CO<sub>2</sub> rich liquid comprises flashing at least said first stream of CO<sub>2</sub> rich liquid and recovering an end flash gas,
- liquefying comprises performing a heat exchange between at least a second part of the compressed feed and the end flash gas in an eighth heat exchanger in order to obtain a third stream of CO<sub>2</sub> rich liquid and a heated end flash gas,
- obtaining the CO<sub>2</sub> rich liquid comprises flashing said third stream of CO<sub>2</sub> rich liquid; and
- using a pump to increase a pressure of the CO<sub>2</sub> rich liquid.

**[0011]** The disclosure also proposes an installation comprising:

- a compression unit adapted for receiving a feed comprising gaseous wet CO<sub>2</sub> and producing a compressed feed and one or several streams of liquid,
- a first cooling cycle, in which a first refrigerant is intended to circulate, and
- a liquefaction unit adapted for liquefying the compressed feed and producing a CO<sub>2</sub> rich liquid,

wherein the liquefaction unit comprises a first heat exchanger adapted for performing a heat exchange between at least a first portion of the compressed feed and a cold fluid in order to obtain a first stream of CO<sub>2</sub> rich liquid and a partially heated gas, the CO<sub>2</sub> rich liquid being intended to be obtained from at least the first stream of CO<sub>2</sub> rich liquid,

wherein the compression unit comprises a second heat exchanger adapted for cooling the feed, the feed receiving cold from a cooling stream of the first refrigerant, the first cooling cycle including a third heat exchanger adapted for allowing the first refrigerant to receive cold from the partially heated gas.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0012]** The disclosure and its advantages will be better understood upon reading the following description, given solely by way of example and with reference to the appended drawing, in which:

Figure 1 is a schematic diagram representing part of an installation according to the disclosure, and Figure 2 is a schematic diagram representing an-

other part of the installation partially shown in Figure 1, the other part comprising the second cooling cycle.

#### 5 DETAILED DESCRIPTION

**[0013]** In all what follows, we will designate by the same references a current circulating in a pipe and the pipe which transports it. The terms "upstream" and "downstream" are generally relative to the normal direction of circulation of a fluid.

**[0014]** Furthermore, unless otherwise stated, percentages are molar percentages, and pressures are given in absolute bar.

**[0015]** The ambient temperature prevailing around the installation is not significant for the purposes of the disclosure and can be in particular between 5°C and 40°C.

#### 20 Installation

**[0016]** An installation 10 according to the disclosure will now be described with reference to Figures 1 and 2.

**[0017]** The installation 10 is adapted for compressing and liquefying a feed 12 comprising gaseous, for example wet, CO<sub>2</sub> (Figure 1) and obtaining a CO<sub>2</sub> rich liquid 14.

**[0018]** The feed 12 for example comes from a CO<sub>2</sub> capture unit 15. The feed 12 for example contains more than 90% of CO<sub>2</sub> on a dry basis, preferably more than 95%. The feed 12 may contain light elements, such as nitrogen, hydrogen or methane. The feed 12 may also contain water, which is then removed in order to prevent hydrate formation or freezing, and to allow liquefying CO<sub>2</sub>. The feed may be at a feeding pressure comprised between 0.1 and 5.0 bar.

**[0019]** By "CO<sub>2</sub> rich" in the present document, it is meant that the CO<sub>2</sub> fraction is "between 90.0% and 100.0%, preferably between 95.0%, and 100.0%".

**[0020]** The CO<sub>2</sub> rich liquid 14 is preferably at a pressure comprised between 6.0 and 70 bar.

**[0021]** As seen in Figure 1, the installation 10 comprises a compression unit 16 adapted for receiving the feed 12 and producing a compressed feed 18 and in the example several streams of liquid 20A, 20B, 20C, and optionally a dehydration unit 22 adapted for dehydrating the compressed feed 18. The installation 10 comprises a liquefaction unit 26 adapted for liquefying the compressed and optionally dehydrated feed 18 and producing the CO<sub>2</sub> rich liquid 14. The installation 10 comprises a first cooling cycle 28, in which a first refrigerant 30 is intended to circulate, in order to bring cold to the compression unit 16.

**[0022]** In case the feed 12 is dry enough, the dehydration unit 22 is not needed. Advantageously, the installation 10 comprises a second cooling cycle 32 shown in Figure 2, in which a second refrigerant 34 is intended to circulate, in order to bring cold to the liquefaction unit 26, and optionally to the first cooling cycle 28.

**[0023]** The installation 10 comprises a first heat exchanger 36 within the liquefaction unit 26, and a second heat exchanger 38 within the compression unit 16 and the first cooling cycle 28, and a third heat exchanger 40 within the first cooling cycle 28.

**[0024]** Advantageously, the installation 10 comprises a fourth heat exchanger 41 within the liquefaction unit 26, a fifth heat exchanger 42 within the first cooling cycle 28 and the second cooling cycle 32, a sixth heat exchanger 44 and a seventh heat exchanger 46 both within the liquefaction unit 26 and the second cooling cycle 32, and an eighth heat exchanger 48 within the liquefaction unit 26.

**[0025]** Apart from the second heat exchanger 38, the compression unit 16 for example comprises a suction drum 50, and a compressor 52 for example having a low pressure stage 52A and a high pressure stage 52B.

**[0026]** In the example, the compressor 52 comprises a low pressure desuperheater 54A (or intercooler), a high pressure desuperheater 54B, a high pressure stage suction drum 56A and a high pressure stage discharge drum 56B.

**[0027]** The low pressure is higher than the feeding pressure, and for example comprised between 0.3 and 7.0 bar.

**[0028]** The high pressure is higher than the low pressure, and for example comprised between 8.0 and 25 bar.

**[0029]** In variants (not shown), the compressor 52 may have a single stage, a single desuperheater 54B and a single discharge drum 56B, or may have three stages or more, each stage having a dedicated desuperheater and suction drum.

**[0030]** The second heat exchanger 38 is advantageously located downstream of the desuperheater 54B and upstream of the discharge drum 56B of the last stage of the compressor 52.

**[0031]** As a variant (not shown), the second heat exchanger 38, the discharge drum 56B and the optional dehydration unit 22 are located between the suction drum 56A and the high pressure stage 52B. Apart from the second heat exchanger 38, the third heat exchanger 40 and the optional fifth heat exchanger 42, the first cooling cycle 28 for example comprises a pump 58 to circulate the first refrigerant 30.

**[0032]** The first refrigerant 30 advantageously comprises, or is, glycol water.

**[0033]** The dehydration unit 22 may be adapted to use various known technologies, and for example comprises one or several molecular sieve(s), silica gel, or triethylene glycol (TEG) (not shown).

**[0034]** Apart from the first heat exchanger 36 and the optional fourth heat exchanger 41 and eighth heat exchanger 48, the liquefaction unit 26 for example comprises an end flash drum 60 and a pump 62.

**[0035]** The liquefaction unit 26 is adapted for receiving a cold fluid 64, such as LNG (liquefied natural gas). LNG is a liquid, usually at a temperature below -140°C. The

cold fluid 64 may be a pressurized one, with a pressure for example above 31 bar or even above 81 bar. The liquefaction unit 26 is adapted for producing a partially heated gas 66 by heating the cold fluid 64, and advantageously for producing an end flash gas 68.

**[0036]** The partially heated gas 66, once heated in the third heat exchanger 40 advantageously becomes a fluid 70 at ambient temperature, or close to, which can for example be exported to a network 72 or a user.

**[0037]** The end flash gas 68 may be recycled in a process unit 73, which can be part of the installation 10 or be an outside unit.

**[0038]** The first heat exchanger 36 is advantageously an intermediate fluid liquefier (IFL) using an intermediate fluid 74, for example comprising more than 90% of ethane or an equivalent fluid, such as propane, ethylene, propylene or ammonia. For example, the intermediate fluid 74 is ethane.

**[0039]** As shown in Figure 2, apart from the fifth heat exchanger 42, the sixth heat exchanger 44 and the seventh heat exchanger 46, the second cooling cycle 32 for example comprises a compressor 76, which is for example three staged, a medium pressure desuperheater 78, a pressure booster 80, a high pressure desuperheater 82A, a condenser 82B, and an accumulator 84. The second cooling cycle 32 for example comprises three expansion organs 86A, 86B, 86C, such as valves or turbines, and three suction drums 88A, 88B, 88C. The second cooling cycle 32 for example comprises a by-pass 90 for by-passing the fifth heat exchanger 42 totally or partially.

**[0040]** As a variant (not shown), the booster 80 may be a final stage of the compressor 76, or the second cooling cycle 32 has no booster.

**[0041]** In another variant (not shown), the compressor 76 may be a single staged machine.

**[0042]** The by-pass 90 for example comprises an expansion organ 86D, such as a valve or a turbine.

**[0043]** The second refrigerant 34 may be any type of refrigerant that can cool and liquefy CO<sub>2</sub>.

**[0044]** In a preferred embodiment, the second refrigerant 34 is a CO<sub>2</sub> rich fluid, advantageously obtained from the compressed and optionally dehydrated feed 18. In other words, the second refrigerant 34 is advantageously made up from the compressed feed 18.

#### Method

**[0045]** The operation of the installation 10 will now be described, thus illustrating a method according to the disclosure.

**[0046]** The feed 12 is first obtained, in the example from the capture unit 15.

**[0047]** The feed 12 is compressed and dried in the compression unit 16 in order to obtain the compressed feed 18 and the streams of liquid 20A, 20B, 20C.

**[0048]** In the example, the feed 12 is received in the suction drum 50, in which water, and other liquids if any,

are collected to form the stream of liquid 20A.

**[0049]** The feed 12 then enters the compressor 52, in the example via the first stage 52A, where pressure is increased from the feeding pressure to the low pressure. The feed 12 is cooled in the low pressure desuperheater 54A and admitted in the high pressure stage suction drum 56A, from which the second stream of liquid 20B is extracted. The feed 12 then enters the second stage 52B, where pressure is increased from the low pressure to the high pressure. In the example, the feed 12 is cooled in the high pressure desuperheater 54B.

**[0050]** Then, the feed 12 is cooled by receiving cold in the second heat exchanger 38 from a cooling stream 92 of the first refrigerant 30. After this additional cooling, the feed 12 is admitted in the high pressure discharge drum 56B from which the stream of liquid 20C is extracted.

**[0051]** The second heat exchanger 38 provides additional cooling to the feed 12 compared to what the desuperheater 54B can do, which allows condensing more water before the compressed feed 18 flows into the optional dehydration unit 22 and thus allows reducing the size of the dehydration unit 22, if any.

**[0052]** Advantageously, the feed 12 is cooled to the minimum possible temperature down while preventing the formation of CO<sub>2</sub> hydrates or ice in the feed.

**[0053]** In the example, the first refrigerant 30 is circulated in the first cooling cycle 28 by the pump 58. The first refrigerant 30, after exiting the second heat exchanger 38, is cooled in the third exchanger 40 by receiving cold from the partially heated gas 66, which is in the example natural gas still rather cold. This produces the fluid 70 at ambient temperature (or close to) which is advantageously exported to the network 72 or a user.

**[0054]** In the example, the first refrigerant 30, after passing in the third exchanger 40, is further cooled in the fifth heat exchanger 42 by receiving cold from the second refrigerant 34, in order to obtain the cooling stream 92.

**[0055]** When operating the first cooling cycle 28, the temperature of the cooling stream 92 is advantageously controlled above the temperature of CO<sub>2</sub> hydrate formation in the feed 12 flowing in the second heat exchanger 38, in order to prevent such formation.

**[0056]** The compressed feed 18 is optionally dehydrated in the dehydrating unit 22.

**[0057]** The compressed feed 18 is then liquefied in the liquefaction unit 26 in order to obtain the CO<sub>2</sub> rich liquid 14.

**[0058]** Advantageously, at least a first part 93 of the compressed feed 18 is precooled in the fourth heat exchanger 41 by heat exchange with a partially heated fluid 67 coming from the first heat exchanger 36, in order to obtain a precooled CO<sub>2</sub> rich gas 94 and to heat the partially heated fluid 67.

**[0059]** The temperature of the partially heated gas 66 entering the fourth exchanger 41 (precooling) is advantageously controlled above the CO<sub>2</sub> freezing temperature, so that no freezing occurs in the fourth exchanger

41.

**[0060]** A heat exchange between at least a first portion 96 of the compressed feed 18 and the cold fluid 64 is performed in the first heat exchanger 36 in order to obtain a first stream 98 of CO<sub>2</sub> rich liquid and the partially heated fluid 67. In the example, the first portion 96 is at least a portion the precooled CO<sub>2</sub> rich gas 94.

**[0061]** As variants (not shown), there is no precooling of the first part 93 (no fourth exchanger 41), or the first portion 96 is not a portion of the precooled CO<sub>2</sub> rich gas 94, but a portion or the totality of the compressed feed 18 which is not precooled.

**[0062]** In the first heat exchanger 36, the intermediate fluid 74 is vaporized by heat exchange with the first portion 96 of the compressed feed 18, for example in a first section 36A of the first heat exchanger 36. The vaporized intermediate fluid 74 for example goes up in a second section 36B of the first heat exchanger 36 where it is condensed by heat exchange with the cold fluid 64. The condensed intermediate fluid 74 for example returns by gravity to the first section 36A below, where the intermediate fluid 74 is vaporized again. The first portion 96 is thus liquefied and the cold fluid 64 thus heats and/or evaporates.

**[0063]** The first heat exchanger 36 may be a single piece of equipment, or two separate pieces of equipment comprising or forming section 36A and section 36B respectively.

**[0064]** The operating pressure of the intermediate fluid 74 allows controlling its temperature, and therefore the temperature of the first stream 98 of CO<sub>2</sub> rich liquid. This is also used to ensure that the liquid intermediate fluid 74 has a temperature above the CO<sub>2</sub> freezing temperature.

**[0065]** The use of the intermediate fluid 74 in the way described above may not allow to heat all the cold fluid 64 to ambient temperature. This may depend on what the operating pressure of the cold fluid 64 is, and what the temperature of the first stream 98 of CO<sub>2</sub> rich liquid to be reached is.

**[0066]** For instance, when trying to cool and liquefy CO<sub>2</sub> entirely with LNG, the amount of LNG needed depends entirely on the exit temperature of the vaporized LNG. If the objective is to warm up entirely the LNG/NG to ambient temperature, so that it can be exported, the heat exchange between CO<sub>2</sub> and LNG will set the LNG flow needed. If the LNG pressure is high (typically above 31 bar), the amount of LNG needed implies that LNG vaporizes at a temperature that is warmer than the CO<sub>2</sub> liquefaction temperature, while it is not possible to liquefy CO<sub>2</sub> with LNG that is too warm. This is known as a pinch effect. If the LNG pressure is low (typically below 31 bar), the pinch effect does not occur, and the entire heat exchange can take place in the first heat exchanger 36.

**[0067]** For the high LNG pressure case (above 31 bar), when a pinch may be encountered, the flow of the cold fluid 64 can be increased relative to the flow of the first portion 96. Then, thanks to the excess of the cold fluid 64, the temperature of the partially heated fluid 67 will remain

colder, and the pinch effect is avoided. However, due to the relatively large amount of the cold fluid 64, the partially heated fluid 67 exiting the first heat exchanger 36 is colder and cannot be sent directly to an export grid. As part of this disclosure, the fourth heat exchanger 41 (precooler) and the third heat exchanger 40 (glycol water cooler) allow to warm-up the partially heated gas 66 (cold natural gas in the example) to ambient temperature so that it can be exported, while its energy is recovered. This improves the overall efficiency of the installation 10.

**[0068]** The CO<sub>2</sub> rich liquid 14 is obtained from at least the first stream 98 of CO<sub>2</sub> rich liquid. For example, the first stream 98 of CO<sub>2</sub> rich liquid is flashed in the end flash drum 60 in order to obtain the CO<sub>2</sub> rich liquid 14 and the end flash gas 68. This enables to improve the quality (purity) of the first stream 98 of CO<sub>2</sub> rich liquid, since some light components, if any, go in the end flash gas 68.

**[0069]** The CO<sub>2</sub> rich liquid 14 is advantageously pumped by the pump 62 at a target export pressure. This advantageously reduces the power required by the CO<sub>2</sub> compressor 52 and improves the overall efficiency of the installation 10.

**[0070]** The target export pressure of the CO<sub>2</sub> rich liquid 14 may be lower than the liquefaction pressure, in which case the pump 62 is not required.

**[0071]** Advantageously, in case there is not enough cold fluid 64, or in order to increase the flow of cold fluid 64 relative to the flow of the first portion 96 for avoiding a pinch effect in the first heat exchanger 36, a second portion 100 of the compressed feed 18 is cooled by heat exchange with the second refrigerant 34 in order to obtain a second stream 102 of CO<sub>2</sub> rich liquid.

**[0072]** For example, the second portion 100 does not flow in the first heat exchanger 36 and is diverted from the precooled CO<sub>2</sub> rich gas 94 toward the sixth heat exchanger 44, and then advantageously the seventh heat exchanger 46. Using two heat exchangers, corresponding to at least two pressure levels in the second cooling cycle 32 allows a better efficiency.

**[0073]** However, in other embodiments (not shown), only one of the sixth heat exchanger 44 and the seventh heat exchanger 46 may be present.

**[0074]** In short, the sixth heat exchanger 44 and the seventh heat exchanger 46 allow not to reduce the flow of liquefied CO<sub>2</sub> produced in case there is not enough cold fluid 64, and/or allow overcoming the pinch effect without reducing the flow of liquefied CO<sub>2</sub> produced. The fourth heat exchanger 41 and the third heat exchanger 40 allow recovering the amount of cold still contained in the partially heated fluid 67 and the partially heated gas 66, this amount being particularly large when the cold fluid 64 is at a high pressure, for example above 31 bar.

**[0075]** The CO<sub>2</sub> rich liquid 14 is obtained from the second stream 102 of CO<sub>2</sub> rich liquid, which is for example mixed with the first stream 98 to be flashed in the end flash drum 60 and pumped by the pump 62.

**[0076]** Advantageously, a heat exchange is performed between at least a second part 104 of the compressed

feed 18 and the end flash gas 68 in the eighth heat exchanger 48 in order to obtain a third stream 106 of CO<sub>2</sub> rich liquid and to heat the end flash gas 68.

**[0077]** The third stream 106 is for example mixed with the first stream 98 and/or the second stream 102 to be flashed and pumped.

**[0078]** The second refrigerant 34 circulates in the second cooling cycle 32 (Figure 2) which, in the example, involves four pressure levels, with the expansion organs 86A, 86B, and 86C or 86D in between the pressure levels.

**[0079]** In variants (not shown), simpler cooling cycles are possible, in particular with less pressure levels.

**[0080]** The second refrigerant 34 is recovered from the suction drums 88A to 88C and is compressed in the compressor 76, which in the example has three stages. The compressed second refrigerant 34 is then cooled in the medium pressure desuperheater 78 (or intercooler), and its pressure is advantageously further increased in the booster 80. The second refrigerant then flows for example through the high pressure desuperheater 82A and the condenser 82B, and is recovered in the accumulator 84.

**[0081]** The CO<sub>2</sub> critical point is at 31 °C. Therefore, CO<sub>2</sub> does not condense if its temperature is higher. The ability to condense CO<sub>2</sub> below its critical point temperature with a cooling media provides an important advantage. However, in case the cooling media temperature does not allow to condense CO<sub>2</sub> at a temperature below 31°C, CO<sub>2</sub> is compressed sufficiently higher than its critical pressure, behaves like a liquid (even though it is not) and provides cooling when it is let down.

**[0082]** Coming from the accumulator 84, at least a stream 108 or all of the second refrigerant 34 is expanded in the expansion organ 86A in order to obtain a first cold stream 110 of the second refrigerant 34. A heat exchange is performed between the first cold stream 110 and the first refrigerant 30 in the fifth heat exchanger 42 in order to obtain the cooling stream 92 of the first refrigerant 30.

**[0083]** Optionally, some or all of the second refrigerant 34 may flow through the by-pass 90 to avoid the fifth heat exchanger 42 and be expanded in the expansion organ 86D.

**[0084]** After expansion, the second refrigerant 34 enters the suction drum 88A and a liquid stream 112 is recovered and expanded in the expansion organ 86B in order to obtain a second cold stream 114 of the second refrigerant 34. A heat exchange is performed between the second cold stream 114 and the second portion 100 of the compressed feed 18 in the sixth heat exchanger 44 in order to obtain the cold CO<sub>2</sub> rich gaseous stream 118.

**[0085]** The remaining liquid fraction of second refrigerant 34, stream 116, is expanded in the expansion organ 86C in order to obtain a third cold stream 120 of the second refrigerant 34. A heat exchange is performed between the third cold stream 120 and the gaseous stream 118 in the seventh heat exchanger 46 in order to obtain the second stream 102 of CO<sub>2</sub> rich liquid.

**[0086]** Depending on the site facilities availability, cooling can be provided with LNG (or any other cold fluid 64). Maximum usage of those is considered to optimise the overall efficiency of the installation 10. This reduces the amount of power consumed by the second cooling cycle 32. For instance, LNG from an LNG receiving terminal (not shown) may be considered. Instead of vaporizing LNG (before sending it as vapor to a distribution network), LNG may be vaporized in the first heat exchanger 36. The operating pressure of LNG may be adapted and compatible with export of the fluid 70 (natural gas). Similarly, in case the LNG receiving terminal uses seawater to vaporize LNG, the seawater may be used by the installation 10 instead (since not used anymore by the LNG terminal, as the LNG is vaporized in the first heat exchanger 36).

**[0087]** Thanks to the above described features, the installation 10 allows reducing the cost and energy consumption for producing the CO<sub>2</sub> rich liquid 14.

**[0088]** The method uses the cold fluid 64, such as LNG. The optional use of the intermediate fluid 74, and the fourth heat exchanger 41 allow overcoming thermal pinch, CO<sub>2</sub> freezing and mechanical stress issues.

**[0089]** Advantageously, all the energy of the cold fluid 64 is recovered. The overall heat integration provided by the different heat exchangers allows recovering the entire cold energy from LNG for example, since LNG is heated to ambient temperature and can be sent to the network 72 or to a user.

**[0090]** Since water is advantageously condensed upstream of the optional dehydration unit 22, the size and duty of the latter is reduced. This is achieved by further cooling the wet CO<sub>2</sub>, using the first refrigerant 30. The risk of hydrate formation, or even freezing, is avoided by controlling the temperature of the cooling stream 92 of first refrigerant 30 above the CO<sub>2</sub> hydrate formation temperature. Besides, the first refrigerant 30 is cooled using the partially heated gas 66 (cold natural gas in the example). Additional cooling of the first refrigerant 30 may be provided by the second cooling cycle 32 if needed.

**[0091]** In case there is not enough cold fluid 64 (LNG in the example) to liquefy CO<sub>2</sub>, the second cooling cycle 32 may be used to provide additional cooling to the liquefaction unit 26. Any type of refrigerant compatible for this service may be used, but as part of the disclosure, some of the compressed and optionally dehydrated feed 18 may be used as the second refrigerant 34. The second cooling cycle 32 may involve only one pressure stage, or multiple pressure stages for better efficiency. Depending on the operating pressure of the cold fluid 64, and the CO<sub>2</sub> precooling achieved in the fourth heat exchanger 41, the number of pressure stages in the second cooling cycle 32 may be adapted.

**[0092]** Using the final pump 62 allows liquefying CO<sub>2</sub> before it is fully compressed to its final pressure, which reduces the power required by the CO<sub>2</sub> compressor 52 and improves the overall efficiency of the installation 10.

**[0093]** The streams 98, 102 and/or 106 of CO<sub>2</sub> rich

liquid are advantageously flashed in the end flash drum 60. This allows removing most of the light components that may be present. Liquid CO<sub>2</sub> quality (composition) is also improved. The end flash gas 68 is advantageously sent to the eighth exchanger 48 where the cold of the end flash gas may be recovered for liquefaction. Once the end flash gas 68 is warm, it can be recycled back to the process unit 73.

**[0094]** The integration of the process of liquefaction of CO<sub>2</sub> with the vaporization of LNG improves the efficiency of the process. The method can accommodate with the use of LNG at high pressure (above 31 bar) or at low pressure (below 31 bar). Utilities available from an LNG terminal may be shared with the installation 10 (such as cooling sea water, etc...) to further improve its efficiency.

## Claims

1. A method comprising:

- obtaining a feed (12) comprising gaseous CO<sub>2</sub>,
- compressing said feed (12) in order to obtain a compressed feed (18) and one or several streams of liquid (20A, 20B, 20C), and
- liquefying the compressed feed (18) in order to obtain a CO<sub>2</sub> rich liquid (14), wherein liquefying comprises:
  - performing a heat exchange between at least a first portion (96) of the compressed feed (18) and a cold fluid (64) in a first heat exchanger (36) in order to obtain a first stream (98) of CO<sub>2</sub> rich liquid and a partially heated gas (66), and
  - obtaining the CO<sub>2</sub> rich (14) liquid from at least the first stream (98) of CO<sub>2</sub> rich liquid,

wherein compressing said feed (12) comprises:

- cooling the feed (12) in a second heat exchanger (38), the feed (12) receiving cold from a cooling stream (92) of a first refrigerant (30), and
- operating a first cooling cycle (28), in which the first refrigerant (30) circulates and receives cold in a third heat exchanger (40) from the partially heated gas.

2. The method according to claim 1, wherein said gaseous CO<sub>2</sub> is wet, the method comprising dehydrating the compressed feed (18) prior to liquefying the compressed feed (18).

3. The method according to claim 1 or 2, wherein the cold fluid (64) is LNG.

4. The method according to any one of claims 1 to 3, wherein the first heat exchanger (36) uses an intermediate fluid (74) evaporating by heat exchange with said first portion (96) of the compressed feed (18),

and condensing by heat exchange with the cold fluid (64).

5. The method according to claim 4, wherein the intermediate fluid (74) comprises more than 90mol.% of ethane, ethylene, propane, propylene or ammonia. 5
6. The method according to any one of claims 1 to 5, wherein liquefying comprises precooling at least a first part (93) of the compressed feed (18) by heat exchange with the partially heated gas (66) in a fourth heat exchanger (41) in order to obtain a pre-cooled CO<sub>2</sub> rich gas (94) and to heat the partially heated gas (66), the first portion (96) of the compressed feed (18) admitted in the first heat exchanger (36) being at least a part of the pre-cooled CO<sub>2</sub> rich gas (94). 10 15
7. The method according to any one of claims 1 to 6, wherein liquefying comprises: 20
  - cooling at least a second portion (100) of the compressed feed (18) by heat exchange with a second refrigerant (34) in order to obtain a second stream (102) of CO<sub>2</sub> rich liquid, 25
  - operating a second cooling cycle (32) in which the second refrigerant (34) circulates, and
  - obtaining the CO<sub>2</sub> rich liquid (14) from at least the second stream (102) of CO<sub>2</sub> rich liquid. 30
8. The method according to claim 7, wherein the second refrigerant (34) is a CO<sub>2</sub> rich fluid obtained from the compressed feed (18).
9. The method according to claim 7 or 8, wherein operating the second cooling cycle (32) includes expanding a stream (108) of the second refrigerant (34) in order to obtain a first cold stream (110) of the second refrigerant (34) and performing a heat exchange between the first cold stream (110) and the first refrigerant (30) in a fifth heat exchanger (42) in order to obtain the cooling stream (92) of the first refrigerant (30). 35 40
10. The method according to any one of claims 7 to 9, wherein operating the second cooling cycle (32) includes: 45
  - expanding a liquid stream (112) of the second refrigerant (34) in order to obtain a second cold stream (114) of the second refrigerant (34), 50
  - performing a heat exchange between the second cold stream (114) and said part (100) of the compressed feed (18) in a sixth heat exchanger (44) in order to obtain a cold CO<sub>2</sub> rich gaseous stream 118 and a liquid stream (116) of the second refrigerant (34), 55
  - expanding the liquid stream (116) of the second

refrigerant (34) in order to obtain a third cold stream (120) of the second refrigerant (34), and - performing a heat exchange between the third cold stream (120) and said gaseous stream (118) in a seventh heat exchanger (46) in order to obtain said second stream (102) of CO<sub>2</sub> rich liquid.

11. The method according to any one of claims 1 to 10, wherein the first refrigerant (30) comprises glycol.
12. The method according to any one of claims 1 to 11, wherein operating the first cooling cycle (28) includes controlling a temperature of said cooling stream (92) of the first refrigerant (30) in order to prevent formation of CO<sub>2</sub> hydrates in the feed (12) in the second heat exchanger (38).
13. The method according to any one of claims 1 to 12, wherein:
  - obtaining the CO<sub>2</sub> rich liquid (14) comprises flashing at least said first stream (102) of CO<sub>2</sub> rich liquid and recovering an end flash gas (68),
  - liquefying comprises performing a heat exchange between at least a second part (104) of the compressed feed (18) and the end flash gas (68) in an eighth heat exchanger (48) in order to obtain a third stream (106) of CO<sub>2</sub> rich liquid and a heated end flash gas (68), and
  - obtaining the CO<sub>2</sub> rich liquid (14) comprises flashing said third stream (106) of CO<sub>2</sub> rich liquid.
14. The method according to any one of claims 1 to 13, comprising using a pump (62) to increase a pressure of the CO<sub>2</sub> rich liquid (14).

**15. An installation (10) comprising:**

- a compression unit (16) adapted for receiving a feed (12) comprising gaseous wet CO<sub>2</sub> and producing a compressed feed (18) and one or several streams of liquid (20A, 20B, 20C),
- a first cooling cycle (28), in which a first refrigerant (30) is intended to circulate, and
- a liquefaction unit (26) adapted for liquefying the compressed feed (18) and producing a CO<sub>2</sub> rich liquid (14),

wherein the liquefaction unit (26) comprises a first heat exchanger (36) adapted for performing a heat exchange between at least a first portion (96) of the compressed feed (18) and a cold fluid (64) in order to obtain a first stream (98) of CO<sub>2</sub> rich liquid and a partially heated gas (66), the CO<sub>2</sub> rich liquid (14) being intended to be obtained from at least the first stream (98) of CO<sub>2</sub> rich liquid,



wherein the compression unit (16) comprises a second heat exchanger (38) adapted for cooling the feed (12), the feed (12) receiving cold from a cooling stream (92) of the first refrigerant (30), the first cooling cycle (28) including a third heat exchanger (40) adapted for allowing the first refrigerant (30) to receive cold from the partially heated gas (66).

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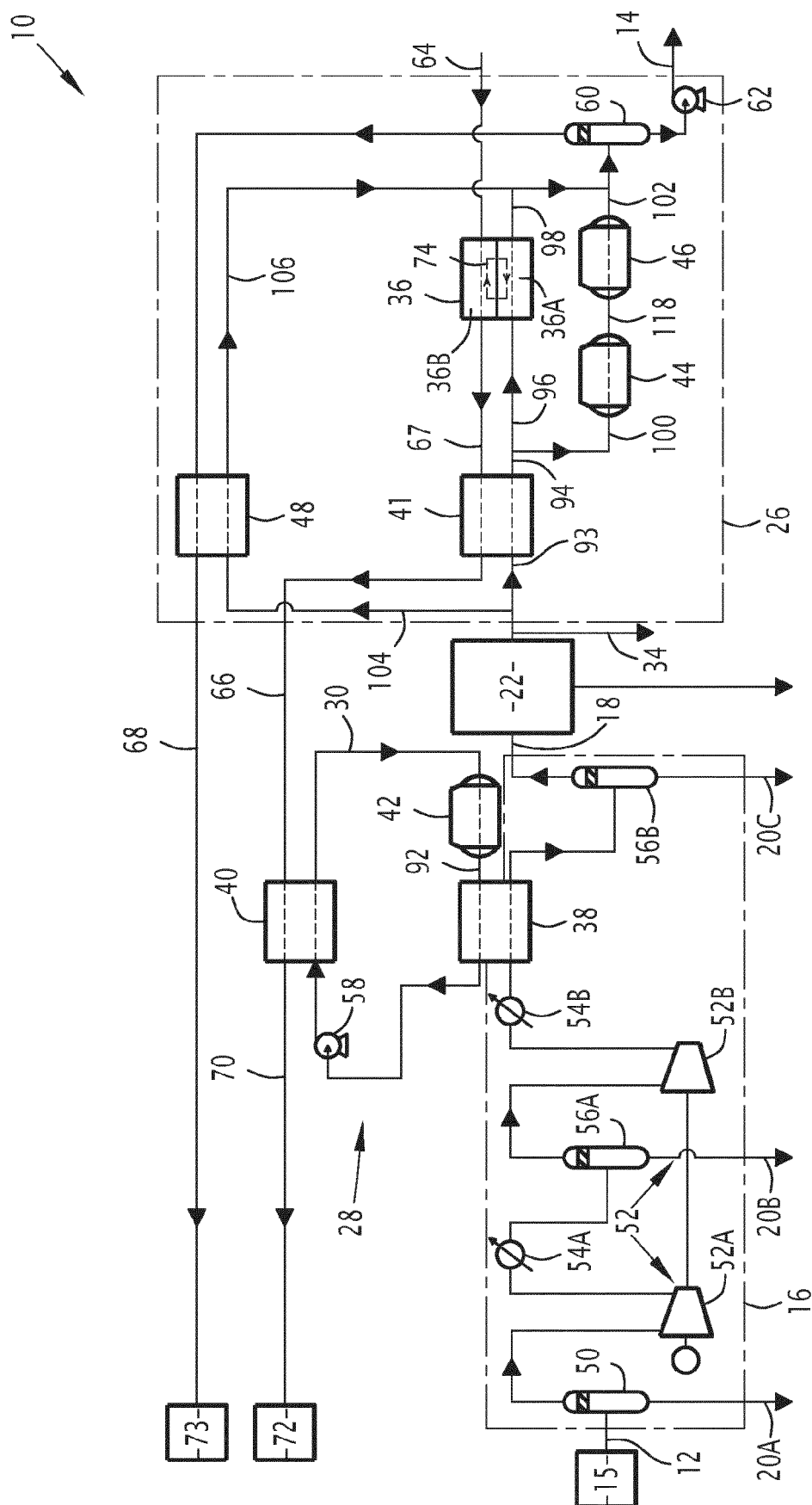
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**FIG. 1**





## EUROPEAN SEARCH REPORT

Application Number

EP 23 30 7196

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| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                        |                                                             |                                            |
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| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Citation of document with indication, where appropriate, of relevant passages                                                                          | Relevant to claim                                           | CLASSIFICATION OF THE APPLICATION (IPC)    |
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| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                        |                                                             |                                            |
| Place of search<br><b>Munich</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                        | Date of completion of the search<br><b>2 September 2024</b> | Examiner<br><b>Schopfer, Georg</b>         |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                                                                                                                                        |                                                             |                                            |



Application Number

EP 23 30 7196

**CLAIMS INCURRING FEES**

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

**LACK OF UNITY OF INVENTION**

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

**LACK OF UNITY OF INVENTION  
SHEET B**

Application Number

EP 23 30 7196

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-6, 11, 12, 14, 15

Intermediate fluid

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2. claims: 7-10, 13

Second refrigeration cycle using CO<sub>2</sub>

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# ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 23 30 7196

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on  
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02 - 09 - 2024

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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82