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A HYDROCARBON STREAM****Publication Classification**(76) Inventors: **Eduard Coenraad Bras**, The
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Hague (NL)(51) **Int. Cl.**
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C10G 5/06 (2006.01)(52) **U.S. Cl.** **62/630; 62/620**(57) **ABSTRACT**

The present invention relates to a method of treating a hydrocarbon stream such as a natural gas stream, the method at least comprising the steps of: (a) supplying a partially condensed feed stream (10) to a first gas/liquid separator (2), the feed stream (10) having a pressure >50 bar; (b) separating the feed stream (10) in the first gas/liquid separator (2) into a first vaporous stream (20) and a first liquid stream (70); (c) expanding the first vaporous stream (20), thereby obtaining an at least partially condensed first vaporous stream (30); (d) supplying the at least partially condensed first vaporous stream (30) to a second gas/liquid separator (4); (e) separating the stream (30) as supplied in step (d) in the second gas/liquid separator (4) into a second vaporous stream (60) and a second liquid stream (40); (f) increasing the pressure of the second liquid stream (40) to a pressure of at least 50 bar, thereby obtaining a pressurized second liquid stream (50); and (g) returning the pressurized second liquid stream (50) to the first gas/liquid separator (2).

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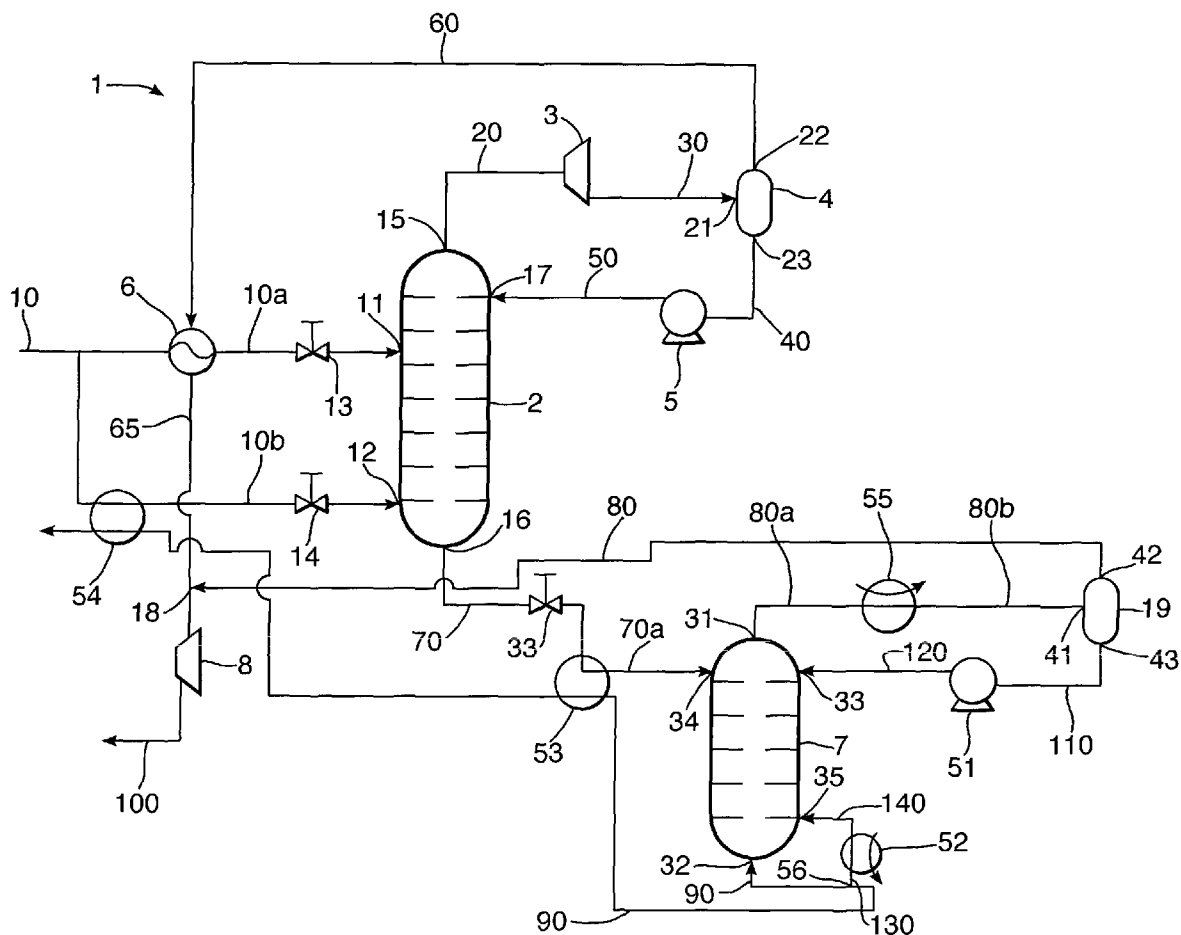
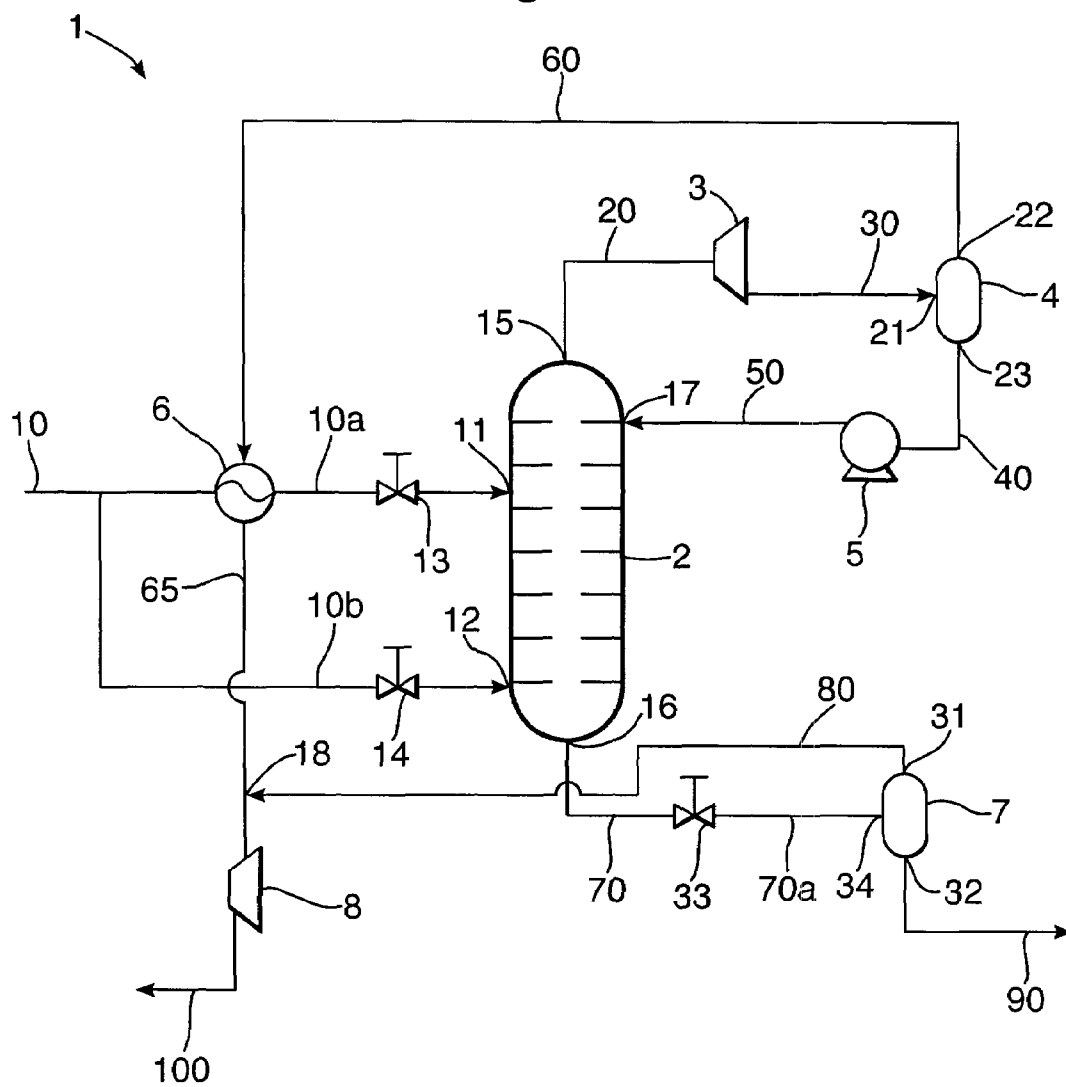
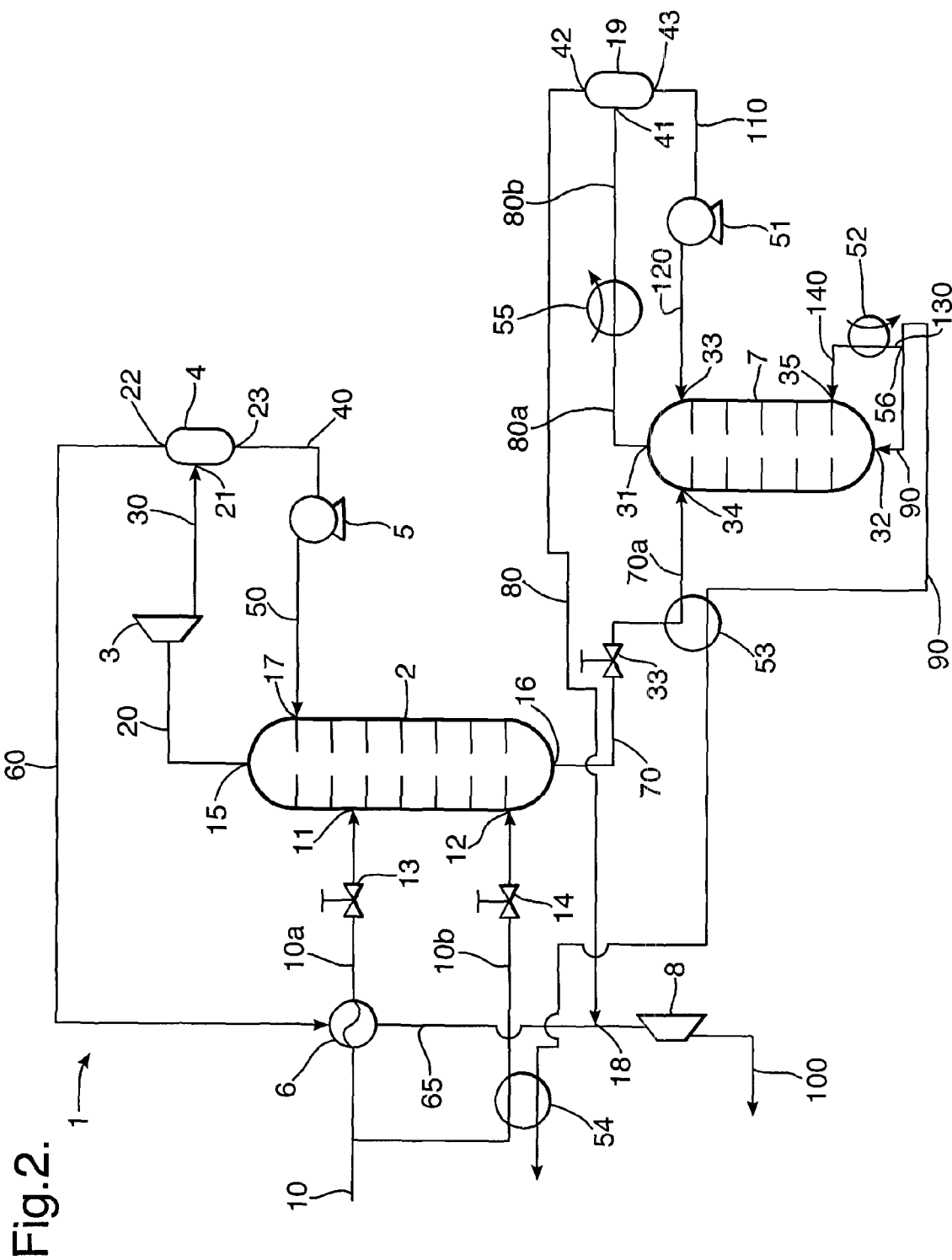


Fig.1





METHOD AND APPARATUS FOR TREATING A HYDROCARBON STREAM

[0001] The present invention relates to a method of treating a hydrocarbon stream such as a natural gas stream, in particular in a process for the production of liquefied natural gas.

[0002] Several methods of treating a natural gas stream are known, e.g. to remove undesired components from the natural gas and/or to meet the required specifications of a client.

[0003] Also, several methods of liquefying a natural gas stream thereby obtaining liquefied natural gas (LNG) are known. It is desirable to liquefy a natural gas stream for a number of reasons. As an example, natural gas can be stored and transported over long distances more readily as a liquid than in gaseous form, because it occupies a smaller volume and does not need to be stored at high pressures.

[0004] Usually, the natural gas stream to be liquefied (mainly comprising methane) contains ethane, heavier hydrocarbons and possibly other components that are to be removed to a certain extent before the natural gas is liquefied. Also to this end, the natural gas stream is treated. One of the treatments may involve the removal of at least some of the ethane, propane and higher hydrocarbons such as butane and propane.

[0005] A known method of treating a natural gas stream is disclosed in U.S. Pat. No. 5,291,736 relating to a method for the liquefaction of natural gas, at the same time separating hydrocarbons heavier than methane.

[0006] As the treating process, whether or not forming part of a liquefaction process, is highly energy consuming there is a constant need to provide alternative processes of treating natural gas, wherein the energy consumption is reduced.

[0007] It is an object of the invention to meet the above need and to provide a process in which the energy consumption is reduced.

[0008] It is a further object of the present invention to provide an alternative method for treating a natural gas stream.

[0009] One or more of the above or other objects are achieved according to the present invention by providing a method of treating a hydrocarbon stream such as a natural gas stream, the method at least comprising the steps of:

[0010] (a) supplying a partially condensed feed stream to a first gas/liquid separator, the feed stream having a pressure $>$ (above) 50 bar;

[0011] (b) separating the feed stream in the first gas/liquid separator into a first vaporous stream and a first liquid stream;

[0012] (c) expanding the first vaporous stream obtained in step (b), thereby obtaining an at least partially condensed first vaporous stream;

[0013] (d) supplying the at least partially condensed first vaporous stream obtained in step (c) to a second gas/liquid separator;

[0014] (e) separating the stream as supplied in step (d) in the second gas/liquid separator into a second vaporous stream and a second liquid stream;

[0015] (f) increasing the pressure of the second liquid stream obtained in step (e) to a pressure of at least 50 bar, thereby obtaining a pressurized second liquid stream; and

[0016] (g) returning the pressurized second liquid stream (50) obtained in step (f) to the first gas/liquid separator.

[0017] In an alternative embodiment, the invention relates to a method of treating a hydrocarbon stream such as a natural gas stream, the method at least comprising the steps of:

[0018] (a) supplying a partially condensed feed stream (10) to a first gas/liquid separator (2), the feed stream (10) preferably having a pressure $>$ 30 bar;

[0019] (b) separating the feed stream (10) in the first gas/liquid separator (2) into a first vaporous stream (20) and a first liquid stream (70);

[0020] (c) expanding the first vaporous stream (20) obtained in step (b), thereby obtaining an at least partially condensed first vaporous stream (30);

[0021] (d) supplying the at least partially condensed first vaporous stream (30) obtained in step (c) to a second gas/liquid separator (4);

[0022] (e) separating the stream (30) as supplied in step (d) in the second gas/liquid separator (4) into a second vaporous stream (60) and a second liquid stream (40);

[0023] (f) increasing the pressure of the second liquid stream (40) obtained in step (e) to a pressure of at least 30 bar, thereby obtaining a pressurized second liquid stream (50); and

[0024] (g) returning the pressurized second liquid stream (50) obtained in step (f) to the first gas/liquid separator (2).

[0025] It has surprisingly been found that using the method according to the present invention, a significant reduction of energy consumption may be obtained. The method according to the invention is especially advantageous as the feed stream is available at a relatively high pressure, typically $>$ (above) 50 bar, preferably above 55 bar, more preferably above 60 bar.

[0026] Whenever in the specification and claims reference is made to a pressure in bar, this is a pressure in bar (absolute).

[0027] According to the present invention no expensive refrigerant scheme has to be used to cool the first vaporous stream.

[0028] The hydrocarbon stream may be any suitable stream to be treated, but is usually a natural gas stream obtained from natural gas or petroleum reservoirs. As an alternative the natural gas stream may also be obtained from another source, also including a synthetic source such as a Fischer-Tropsch process.

[0029] Usually the natural gas stream is comprised substantially of methane. Preferably the feed stream comprises at least 60 mol % methane, more preferably at least 75 mol %, such as at least 80 mol % methane.

[0030] Depending on the source, the natural gas may contain varying amounts of hydrocarbons heavier than methane such as ethane, propane, butanes and pentanes as well as some aromatic hydrocarbons. The natural gas stream may also contain non-hydrocarbons such as H_2O , mercury, N_2 , CO_2 , H_2S and other sulphur compounds.

[0031] If desired, the feed stream containing the natural gas may be pre-treated before feeding it to the first gas/liquid separator. This pre-treatment may comprise removal of undesired components such as H_2O , mercury, N_2 , CO_2 , H_2S and other sulphur compounds, or other steps such as pre-cooling or pre-pressurizing. As these steps are well known to the person skilled in the art, they are not further discussed here.

[0032] Usually the feed stream has a temperature in the range from ambient to $90^\circ C.$, preferably from $20^\circ C.$ to $80^\circ C.$ Preferably the pressure of the feedstream is in the range

from more than 50 bar to 100 bar, more preferably from more than 55 bar to 90 bar, even more preferably from more than 60 bar to 80 bar.

[0033] The first and second gas/liquid separators may be any suitable means for obtaining a vaporous stream and a liquid stream, such as a vessel, a scrubber, a distillation column, etc. Usually the first gas/liquid separator comprises a column having 1-30 trays, preferably 1-15 trays. In the embodiment of the invention described with reference to FIG. 1, the second gas/liquid separator usually comprises a simple vessel with only one tray. In the embodiment of the invention described with reference to FIG. 2, the second gas/liquid separator preferably comprises a column having 1-30 trays, more preferably 1-15 trays.

[0034] Alternatively the first and second gas/liquid separators may each be provided with packing (random or structured). When the gas/liquid separator is provided with trays, a distillation stage corresponds to one tray, and when the gas/liquid separator is provided with packing (random or structured) a distillation stage corresponds to a theoretical stage.

[0035] Where in the specification and in the claims a level of introducing a stream into the gas/liquid separator is defined relative to introducing another stream, there is at least one distillation stage between the two levels, the same applies to defining the level of removing a stream from the gas/liquid separator. The top of the gas/liquid separator is that part of the gas/liquid separator that is located above the uppermost distillation stage, and the bottom of the gas/liquid separator is that part of the gas/liquid separator that is located below the lowermost distillation stage.

[0036] The first liquid stream and the second vaporous stream may be used as product streams or may be further processed, if desired.

[0037] In step (f) of the method of the present invention, the pressure of the second liquid stream obtained in step (e) is increased to a pressure of at least 50 bar, thereby obtaining a pressurized second liquid stream. Preferably, the pressure of the second liquid stream is increased to a pressure in the range from more than 50 bar to 100 bar, more preferably from more than 55 bar to 90 bar, even more preferably from more than 60 bar to 80 bar.

[0038] Typically, the pressure of the second liquid stream is in the range from 0 to 5 bar higher than the pressure in the first gas/liquid separator, preferably from 0 to 2 bar higher, even more preferably from 0 to 1 bar higher, in particular substantially the same pressure.

[0039] It is preferred according to the present invention that in step (a) the feed stream is supplied as at least two different streams to the first gas/liquid separator, the feed stream comprising a higher feed stream and a lower feed stream. In this embodiment, the higher feed stream is fed at a warmer (i.e. higher) point of the first gas/liquid separator than the lower feed stream (that is fed at a lower, i.e. colder, point of the first gas/liquid separator).

[0040] Further it is preferred that the higher feed stream is cooled, preferably against the second vaporous stream obtained in step (e). To this end a heat exchanger may be used.

[0041] Also it is preferred that the first liquid stream obtained in step (b) is supplied to a third gas/liquid separator thereby obtaining a third vaporous stream and a third liquid stream. Preferably the third vaporous stream is combined with the second vaporous stream.

[0042] In a further aspect the present invention relates to an apparatus for treating a hydrocarbon stream such as a natural gas stream, the apparatus at least comprising:

[0043] a first gas/liquid separator for separating a partially condensed feed stream into a first vaporous stream and a first liquid stream;

[0044] an expander for expanding the first vaporous stream;

[0045] a second gas/liquid separator for separating the expanded first vaporous stream into a second vaporous stream and a second liquid stream; and

[0046] a pressurizing unit for increasing the pressure of the second liquid stream to at least 50 bar before being returned to the first gas/liquid separator.

[0047] Preferably the first gas/liquid separator comprises at least two inlets for the feed stream, including an inlet for a higher feed stream and an inlet for a lower feed stream.

[0048] It is especially preferred that the apparatus further comprises a heat exchanger for cooling the higher feed stream against the second vaporous stream.

[0049] Further it is preferred that the apparatus further comprises a third gas/liquid separator for separating the first liquid stream into a third vaporous stream and a third liquid stream. Preferably the third vaporous stream can be combined with the second vaporous stream.

[0050] Hereinafter the invention will be further illustrated by the following non-limiting drawing. Herein shows:

[0051] FIG. 1 schematically a process scheme in accordance with an embodiment of the present invention; and

[0052] FIG. 2 schematically a process scheme in accordance with another embodiment of the present invention.

[0053] For the purpose of this description, a single reference number will be assigned to a line as well as a stream carried in that line. Same reference numbers refer to similar components.

[0054] FIG. 1 schematically shows a process scheme enabling selective low temperature separation of heavy hydrocarbons (C_5^+) in a gas plant with flexibility to recover/reject LPGs.

[0055] The process scheme (or apparatus) is generally indicated with reference number 1.

[0056] A partially condensed hydrocarbon feed stream 10 such as natural gas is supplied to a first gas/liquid separator 2 at a certain inlet pressure and inlet temperature. In the embodiment of FIG. 1 the feed stream 10 is fed as two different streams, viz. a higher feed stream 10a and a lower feed stream 10b. If desired the feed stream 10 may be split in more than two sub-streams. The higher feed stream 10a is pre-cooled in heat exchanger 6 and fed to the separator 2 at first inlet 11; the lower feed stream 10b is fed to the separator 2 at second inlet 12. In the shown embodiment, stream 10a is cooled against another stream in the process (i.e. stream 60). However, any other cooling may be used, if desired.

[0057] Typically, the feed stream 10 has a temperature in the range from ambient to 90° C., preferably from 20° C. to 80° C. Preferably the pressure of the feedstream is in the range from more than 50 bar to 100 bar, more preferably from more than 55 bar to 90 bar, even more preferably from more than 60 bar to 80 bar. The temperature and pressure of the streams 10a and 10b is chosen to optimise a gas/liquid separation step in separator 2. If desired, the pressure of the streams 10a and 10b may have been adjusted in valves 13 and 14, respectively.

[0058] As mentioned above, stream 10 is fed to the gas/liquid separator 2 as streams 10a and 10b. There, the feed stream 10 is separated into a first vaporous (i.e. overhead) stream 20 and a first liquid (i.e. bottom) stream 70. The overhead stream 20 leaves the separator 2 at first outlet 15 and is enriched in methane (and usually also ethane) relative to the feed stream 10.

[0059] The bottom stream 70 leaves the separator 2 at second outlet 16 and is generally liquid; stream 70 may contain hydrocarbons that can be separately processed to form liquefied petroleum gas (LPG) products. Usually, the bottom stream 70 is subjected to one or more fractionation steps to collect various natural gas liquid products.

[0060] The overhead stream 20 is led to an expander 3, thereby at least partially condensing the stream 20, thereby obtaining stream 30. Subsequently, stream 30 is fed to a second gas/liquid separator 4 at inlet 21. In the second separator 4, the partially condensed stream 30 is separated into a second vaporous (i.e. overhead) stream 60 and a second liquid (i.e. bottom) stream 40. The overhead stream 60 leaves the separator 4 at outlet 22 and is generally vaporous; the bottom stream 40 leaves the separator 4 at outlet 23 and is generally liquid.

[0061] Then the stream 40 is pressurized in pressurizing unit 5 to a pressure of at least 50 bar. The pressurizing unit 5 may be any suitable means for increasing the pressure such as a pump. The pressurized stream 50 leaving the pressurizing unit 5 is subsequently returned to the first gas/liquid separator 2, preferably at the warm (i.e. high) part thereof, at third inlet 17 of the first separator 2.

[0062] The first liquid stream 70 and the second vaporous stream 60 may be used as product streams or may be further processed, if desired.

[0063] In the embodiment as shown in FIG. 1, the second vaporous stream 60 is used to cool the higher feed stream 10a in heat exchanger 6.

[0064] Furthermore, the first liquid stream 70 is (after being optionally depressurized in valve 33) fed (as stream 70a) to a third gas/liquid separator 7 (at inlet 34) thereby obtaining (at outlet 31) a third vaporous stream 80 and (at outlet 32) a third liquid stream 90.

[0065] The third vaporous stream 80 is combined with the second vaporous stream 65 (i.e. stream 60 after being heat exchanged in heat exchanger 6) at junction point 18 and is subsequently compressed in compressor 8 thereby obtaining product gas 100 which will usually be subjected to a liquefaction step in one or more heat exchangers (not shown) thereby obtaining liquefied natural gas (LNG). In case that stream 100 is to be liquefied, some further treatment steps may take place to remove any contaminants that may solidify during the liquefaction process. As an example a (n optionally additional) CO₂ removal step may take place.

[0066] Stream 80 may be compressed to about the same pressure of the second vaporous stream 65 before stream 80 is combined with the second vaporous stream 65 at the junction point 18.

[0067] FIG. 2 schematically shows an alternative embodiment of the present invention to provide an integrated gas dew pointing and condensate stabilizing process, wherein the third column 7 is in the form of a debutanizer/stabilizer, thereby obtaining a third vaporous stream 80 being enriched in butane and lower hydrocarbons (such as methane, ethane and/or propane) relative to the third liquid stream 90.

[0068] Furthermore, FIG. 2 shows that the third vaporous stream 80, before being combined with stream 65 in junction point 18, has previously been cooled (as stream 80a) against (an air cooler or water cooler or, as shown) an external refrigerant in heat exchanger 55, fed (as stream 80b) to a fourth gas/liquid separator 19 at inlet 41, and removed at outlet 42 from the fourth gas/liquid separator 19 (as stream 80). The fourth gas/liquid separator 19 functions as an overhead condenser drum. The liquid bottom stream 110 removed at outlet 43 from the fourth gas/liquid separator 19 is pressurized in pump 51 and returned as stream 120 to the top (at inlet 33) of the debutanizer 7.

[0069] A part of the bottom stream 90 (or 'condensate') of the debutanizer/stabilizer 7 is split off at splitter 56, heat exchanged as stream 130 against an external stream in heat exchanger 52 (functioning as a reboiler) and returned as stream 140 to the bottom (at inlet 35) of the debutanizer/stabilizer 7. The major part of the condensate stream 90 is (after splitter 56) heat exchanged against the first liquid stream 70 in heat exchanger 53 and subsequently against stream 10b in heat exchanger 54 and used as a product stream.

[0070] In addition to or instead of heat exchanging stream 70 (or 70a) against stream 90 (in heat exchanger 53), stream 70 (or 70a) may be heat exchanged against stream 80a, for example in heat exchanger 55.

[0071] If desired, one or more further gaseous and/or liquid streams (not shown) may be introduced into the debutanizer/stabilizer 7.

[0072] The line-up as used in FIG. 2 allows to produce a product gas stream 80 with a surprisingly high content of LPGs (i.e. propane and/or butane) and a condensate stream 90 with a surprisingly high content of C₅⁺ (i.e. pentane and higher components). As indicated above, stream 80 may be used as a separate product stream, but will usually be combined with stream 65 to enrich the latter stream.

[0073] Table I gives an overview of the estimated pressures and temperatures of a stream at various parts in an example process of FIG. 2. Also the mole fraction of methane is indicated. The feed stream in line 10 of FIG. 2 comprised approximately the following composition: 75.2 mole % methane, 9.2 mole % ethane, 4.3 mole % propane, 2.1 mole % butanes, 5.2 mole % C₅⁺, 1.2 mole % N₂ and 2.7 mole % CO₂. H₂S and H₂O were previously removed.

TABLE I

Line	Pressure [bar]	Temperature [° C.]	Methane [mole fraction]
10	67.7	61.1	0.752
20	66.8	-1.0	0.807
30	42.2	-21.3	0.807
40	42.2	-21.3	0.291
50	69.7	-19.2	0.291
60	42.2	-21.3	0.831
65	41.7	85.6	0.831
70	67.0	4.9	0.287
80	42.7	10.0	0.456
90	9.5	173.3	0.0
100	49.6	78.8	0.795
110	8.9	10.0	0.027

[0074] The person skilled in the art will readily understand that many modifications may be made, without departing from the scope of the appended claims.

[0075] As an example, the expander 3 and compressor 8 may be functionally coupled.

1. A method of treating a hydrocarbon stream, the method at least comprising the steps of:

- (a) supplying a partially condensed feed stream to a first gas/liquid separator, the feed stream having a pressure >50 bar;
- (b) separating the feed stream in the first gas/liquid separator into a first vaporous stream and a first liquid stream;
- (c) expanding the first vaporous stream obtained in step (b), thereby obtaining an at least partially condensed first vaporous stream;
- (d) supplying the at least partially condensed first vaporous stream obtained in step (c) to a second gas/liquid separator;
- (e) separating the stream as supplied in step (d) in the second gas/liquid separator into a second vaporous stream and a second liquid stream;
- (f) increasing the pressure of the second liquid stream obtained in step (e) to a pressure of at least 50 bar, thereby obtaining a pressurized second liquid stream; and
- (g) returning the pressurized second liquid stream obtained in step (f) to the first gas/liquid separator.

2. The method according to claim 1, wherein in step (a) the feed stream is supplied as at least two different streams to the first gas/liquid separator, the feed stream comprising a higher feed stream and a lower feed stream.

3. The method according to claim 2, wherein the higher feed stream is cooled before it is supplied to the first gas/liquid separator.

4. The method according to claim 3, wherein the higher feed stream is cooled against the second vaporous stream obtained in step (e).

5. The method according to claim 1, wherein the first liquid stream obtained in step (b) is supplied to a third gas/liquid separator thereby obtaining a third vaporous stream and a third liquid stream.

6. The method according to claim 5, wherein the third vaporous stream is combined with the second vaporous stream.

7. The method according to claim 5, wherein the third liquid stream is heat exchanged against the first liquid stream, before it is supplied to the third gas/liquid separator.

8. The method according to claim 5, wherein the third liquid stream is heat exchanged against the lower feed stream.

9. The method according to claim 5, wherein the third column is a debutanizer, thereby obtaining a third vaporous

stream being enriched in butane and lower hydrocarbons relative to the third liquid stream.

10. The method according to claim 1, wherein the second vaporous stream, is liquefied, thereby obtaining a liquefied hydrocarbon stream.

11. An apparatus for treating a hydrocarbon stream, the apparatus at least comprising:

- a first gas/liquid separator for separating a partially condensed feed stream O into a first vaporous stream and a first liquid stream;
- an expander for expanding the first vaporous stream;
- a second gas/liquid separator for separating the expanded first vaporous stream into a second vaporous stream and a second liquid stream; and
- a pressurizing unit for increasing the pressure of the second liquid stream to a pressure of at least 50 bar before being returned to the first gas/liquid separator.

12. The apparatus according to claim 11, wherein the first gas/liquid separator comprises at least two inlets for the feed stream, including a first inlet for a higher feed stream and a second inlet for a lower feed stream.

13. The apparatus according to claim 12, wherein the apparatus further comprises a heat exchanger for cooling the higher feed stream against the second vaporous stream.

14. The apparatus according to claim 11, wherein the apparatus further comprises a third gas/liquid separator for separating the first liquid stream into a third vaporous stream and a third liquid stream.

15. The apparatus according to claim 14, wherein the third vaporous stream can be combined with the second vaporous stream.

16. The method according to claim 2, wherein the first liquid stream obtained in step (b) is supplied to a third gas/liquid separator thereby obtaining a third vaporous stream and a third liquid stream.

17. The method according to claim 3, wherein the first liquid stream obtained in step (b) is supplied to a third gas/liquid separator thereby obtaining a third vaporous stream and a third liquid stream.

18. The method according to claim 4, wherein the first liquid stream obtained in step (b) is supplied to a third gas/liquid separator thereby obtaining a third vaporous stream and a third liquid stream.

19. The method according to claim 6, wherein the third liquid stream is heat exchanged against the first liquid stream, before it is supplied to the third gas/liquid separator.

20. The method according to claim 6, wherein the third liquid stream is heat exchanged against the lower feed stream.

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