A process is described for removing heavies and lights from a hydrocarbon-rich feed fraction. A heavies-rich liquid is rectification removed (1st removal stage) from a partially condensed feed fraction. Heavies-depleted gas is partially condensed and rectification separated into a methane-rich liquid fraction and a lights-rich gas fraction (2nd removal stage). The 1st removal stage is operated at a pressure of at least 25 bar. The heavies-depleted gas fraction does not undergo pressure elevation before being fed into the 2nd removal stage. Reflux for the 2nd removal stage is produced via an open loop refrigeration cycle. Refrigerant circulating in the open loop refrigeration cycle is vaporized to two different temperature levels against the reflux streams in a head condenser and a side condenser of the 2nd removal stage. The pressure of refrigerant vaporized in the side condenser is at least three times the pressure of refrigerant vaporized in the head condenser.
The invention relates to a process for removing heavies and lights from a hydrocarbon-rich feed fraction, preferably from natural gas, wherein:

a) the feed fraction is partially condensed,

b) a heavies-rich liquid fraction is rectifierly removed (1st removal stage),

c) the resultant, heavies-depleted gas fraction is partially condensed and

d) rectifierly separated into a methane-rich liquid fraction and a lights-rich gas fraction (2nd removal stage).

Natural gas consists not only of methane, its main component, but generally also of components having a higher boiling point, for example ethane, propane and higher alkanes—hereinafter referred to as heavies—and also of components having a lower boiling point, for example nitrogen, hydrogen and helium—hereinafter referred to as lights.

In the natural gas separation process, it may be advantageous for the heating value or Wobbe Index, reduced by the removal of heavies, to be pushed back up by the removal of inert lights—meaning nitrogen and helium.

U.S. Pat. No. 4,504,295 discloses a process of the type in question for removal of heavies and lights from natural gas by combining known processes for removing heavies and lights.

The energy consumption of the single-column process for removing lights which is described in the US patent cited above is generally higher than that achieved on using a more capital-intensive double-column process. However, double-column processes require an upstream enrichment column when the nitrogen concentration of the feed fraction is less than 25 mol%. The operating pressure required for this enrichment column is generally not less than 5 bar above the operating pressure of the methane/ethane (demethanizer) separation column used to remove the heavies. This accordingly makes it necessary to compress the gas between removing the heavies and the lights, or alternatively to perform a total condensation with a subsequent pump in order that the required pressure profile may be established.

It is an object of the present invention to provide a process for removing heavies and lights from natural gas with the energy consumption at the level of a double column arrangement but without requiring any pressure elevation between the removal of heavies and lights.

Upon further study of the specification and appended claims, other objects, aspects and advantages of the invention will become apparent.

These objects are achieved by a process for removing heavies and lights from a hydrocarbon-rich feed fraction, preferably from natural gas, the process being characterized in that:

e) the 1st removal stage is operated at a pressure of at least 25 bar,

f) the heavies-depleted gas fraction does not undergo pressure elevation before being fed into the 2nd removal stage, and

g) the reflux of the 2nd removal stage is produced via an open loop refrigeration cycle,

h) wherein the refrigerant circulating in the open loop refrigeration cycle is vaporized to two different temperature levels against the reflux streams in the head condenser and a side condenser of the 2nd removal stage, and

i) the pressure of the refrigerant vaporized in the side condenser is at least three times the pressure of the refrigerant vaporized in the head condenser.

The invention accordingly combines a preferably carbon dioxide-lean, open loop refrigeration cycle, wherein the refrigerant is vaporized to two different pressure levels, with the physical link between the removal of heavies in the 1st removal stage and the removal of lights in the 2nd removal stage, while the fraction withdrawn from the 1st removal stage and supplied to the 2nd removal stage is not subjected to any pressure elevation.

Further advantageous refinements of the process which the present invention provides for removing heavies and lights from a hydrocarbon-rich feed fraction, preferably from natural gas, are characterized in that:

the 2nd removal stage is realized in a column having a dividing wall, wherein the dividing wall is at least disposed in the region of the column where the column is fed with the heavies-depleted gas fraction and a carbon dioxide-lean fraction, which is admixed to the open loop refrigeration cycle, is withdrawn,

the refrigerant of the open loop refrigeration cycle has a methane content of at least 80 mol%, preferably at least 85 mol%.

the composition of the refrigerant of the open loop cooling cycle corresponds essentially to the composition of the carbon dioxide-lean fraction withdrawn from the 2nd removal stage.

the 1st removal stage is operated at a pressure of at least 28 bar,

the pressure of refrigerant vaporized in the side condenser is at least five times the pressure of refrigerant vaporized in the head condenser,

when the pressure of the hydrocarbon-rich feed fraction is more than 50 bar, the feed fraction is expanded in at least two stages before being fed into the 1st removal stage, and/or

a subset of the heavies-depleted gas fraction obtained in the 1st removal stage is at least temporarily admixed to the methane-rich liquid fraction obtained in the 2nd removal stage.

BRIEF DESCRIPTION OF THE DRAWINGS

The process which the present invention provides for removing heavies and lights from a hydrocarbon-rich feed fraction, and also further refinements thereof, are further elucidated herein below with reference to the exemplary embodiments depicted in FIGS. 1 and 2, wherein:

FIG. 1 illustrates an embodiment in which the second removal stage is realized in a single column T2 with a dividing wall; and

FIG. 2 illustrates an embodiment in which the second removal stage is realized in three interconnected columns T2, T3 and T4.

A natural gas stream comprising lights and heavies and generally having a pressure between 35 and 50 bar passes via line 1 through heat exchangers E1 and E2 and is partially condensed therein against process streams as more particularly discussed herein below. The natural gas stream 2 withdrawn from heat exchanger E2 is separated in separator D1 into a liquid phase 3 and a gas phase 4. The former is fed via expansion valve V1 to the methane/ethane separation column T1 (demethanizer), which embodies the 1st removal stage, in the upper region thereof. The aforementioned gas phase 4 is
expanded in expander X1 and likewise applied to column T1 in the head region thereof. A substream of gas phase 4 generated in separator D1 is applied to column T1 as reflux via expansion valve V4 after splitting into the two substreams 5 and 6, which are condensed in heat exchangers E5 and E2, respectively.

[0030] According to the invention, column T1 is operated at a pressure of at least 25 bar, preferably at least 28 bar. In general, the operating pressure of the 1st removal stage T1 is 25 to 35 bar. The requisite lateral heaters a/b of column T1 are only depicted schematically. A heavies-rich liquid fraction 8 is withdrawn from the base of column T1 and sent to its further use, for example its separation into ethane and a further fraction consisting of propane and higher hydrocarbons. The ethane fraction is frequently used as ethylene plant feed, while the propane-containing fraction is subjected to various chemical operations. A substream 9 of liquid fraction 8 is vaporized in reboiler E3 and returned to column T1.

[0031] The heavies-depleted gas fraction 10 obtained at the top of the first removal stage T1 is partially condensed in heat exchanger E4 and fed via expansion valve V6 to the 2nd column or removal stage T2. According to the present invention, the above-described fraction 10 experiences no pressure elevation due to a pump or a compressor between its withdrawal from the 1st removal stage T1 and its feeding into the 2nd removal stage T2. In general, the operating pressure of the 2nd removal stage T2 is 22 to 32 bar.

[0032] A rectificatory separation takes place in column T2 into a methane-rich liquid fraction 11, which is withdrawn from the base of column T2, and a lights-rich gas fraction 12, which is withdrawn from the head region of column T2. The aforementioned methane-rich liquid fraction 11 is expanded in valve V7 to a pressure from 3 to 15 bar, preferably from 5 to 10 bar below the operating pressure of column T1. This methane-rich fraction is then fully vaporized in heat exchanger E4, subsequently warmed in heat exchangers E2 and E1 and discharged as methane-rich product stream 11'. Analogously, the lights-rich gas fraction 12 withdrawn from the head region of column T2 is warmed in heat exchanger E6 and subsequently sent to its further use, for example the recovery of helium, via line 12'. A substream 13 of the aforementioned methane-rich liquid fraction is at least partly vaporized in heat exchanger E5 and then applied to column T2 in the lower region thereof.

[0033] The second removal stage or column T2 preferably includes a dividing wall T, this being at least disposed in that region of column T2 where the column is fed with the heavies-depleted fraction 10 and a carbon dioxide-lean fraction 25, which will be more particularly discussed herein below, is withdrawn. Dividing wall T prevents physical contact between the two aforementioned fractions.

[0034] According to the invention, the reflux for the second removal stage or column T2 is produced via an open loop refrigeration cycle. The refrigerant of this refrigeration cycle has a methane content of at least 80 mol %, preferably at least 85 mol %. It is particularly advantageous for the composition of the refrigerant of this refrigeration cycle to essentially correspond to the composition of the aforementioned carbon dioxide-lean fraction 25. The refrigerant used for the open loop refrigeration cycle is the aforementioned carbon dioxide-lean, methane-lean fraction 25. It is withdrawn from column T2 via control valve V13, vaporized in side condenser E8, warmed in heat exchangers E5 and E1, fed to the first stage of refrigerant compressor C1 and is compressed, jointly with refrigerant stream 23, which will be more particularly discussed herein below, to an intermediate pressure. After cooling down in intercooler E9, the compressed refrigerant is compressed to the desired cycle pressure in the second compressor stage. After cooling down in aftercooler E10, the compressed refrigerant 20 is split into two substreams which are cooled down separately in heat exchangers E1 and E6 and fully condensed in heat exchanger E5 after mixing has taken place. The fully condensed refrigerant 21 is then fed to the buffer container D4. The two refrigerant substreams 22 and 24 are removed therefrom. The latter substream is subcooled in heat exchanger E5 and then expanded via valve V12 into column T2, while refrigerant substream 22 is subcooled in heat exchanger E6 and fed via expansion valve V11 to the head condenser E7 of column T2. From this head condenser it is withdrawn via line 23, warmed in heat exchanger E6 and then fed to the first stage of cycle compressor C1. To control the mass flows in lines 24 and 25, the latter can be connected together via control valve V14.

[0035] Refrigerant streams 22 and 25 are vaporized against reflux streams 14 and 15, respectively, in head condenser E7 and side condenser E8 such that the pressure of refrigerant 25 vaporized in side condenser E8 is at least three times, preferably five times the pressure of refrigerant 22 vaporized in head condenser E7.

[0036] The effect of the rectification in column T2 and also of dividing wall T disposed therein is that the carbon dioxide concentration in the carbon dioxide-lean refrigerant fraction withdrawn via line 25 is below 50 vppm, preferably below 5 vppm. By providing dividing wall T it is possible for head condenser E7 to be provided with a refrigerant fraction which does not cause solids formation by carbon dioxide even at an operating temperature below −150°C, preferably below −155°C. This ensures that the lights-rich gas fraction 12 withdrawn from the head region of column T2 has a methane content of less than 2% by volume, preferably less than 1% by volume.

[0037] Owing to the above-described splitting to produce the reflux streams 14 and 15 in two different condensers E7 and E8, the energy consumption of compressor unit C1 decreases by at least 30% compared with a process where side condenser E8 is eschewed. The choice of operating pressure for the first removal stage T1 ensures that the lights-rich gas fraction 12 which is withdrawn from the head region of column T2 and which has a nitrogen content of more than 90 mol %, preferably more than 95 mol %, can be at least partly condensed against the refrigerant without causing a pressure below atmospheric pressure on the suction side of cycle compressor C1.

[0038] When the pressure of the hydrocarbon-rich feed fraction 1 is greater than 50 bar, advantageously feed fraction 1 is expanded in at least two stages before being fed into the 1st removal stage T1. To this end, as shown by the exemplary embodiment depicted in FIG. 2, an additional expander X2 is provided. The hydrocarbon-rich feed fraction 40 partially condensed in heat exchanger E1 is separated in a separator D2 into a gas fraction 41 and a liquid fraction 42. Gas fraction 41 is expanded in expander X2, while the aforementioned liquid fraction 42 is expanded in valve V2. The two fractions are subsequently fed to a further separator D3 and again separated therein into a liquid fraction 43, which is fed via expansion valve V3 to the 1st removal stage T1, and a gas fraction 44, which is partially condensed in heat exchanger E2 and fed to downstream separator D1.
In a further advantageous refinement of the process according to the present invention which may serve to relieve the operation of removing the lights in the second removal stage T2, a substream of the heavies-depleted gas fraction obtained in the first removal stage T1 is at least temporarily admixed via line 50, in which a control valve V5 is provided, to the methane-rich liquid fraction obtained in the second removal stage T2.

The lines 51 and 52 depicted in FIG. 2 and the control valves V15 and V16 disposed therein may be used to achieve an optimized distribution for the refrigerant within the refrigeration cycle, and hence a reduction in the energy consumption of compressor unit C1.

In the exemplary embodiment depicted in FIG. 2, the second removal stage is realized in three interconnected columns T2', T3 and T4. Column T3 corresponds to the upper part of column T2 depicted in FIG. 1. The partially condensed stream 60 which is returned from side condenser E8 and which corresponds to stream 15 as depicted in FIG. 1 is fed to the base of column T3. The gas phase of this steam ascends in column T3 and is partially condensed in head condenser E7. Stream 61 withdrawn from the base of column T3 is applied via pump P1 to column T2' as reflux.

Column T4 corresponds to the region of column T2 depicted in FIG. 1 to the right of dividing wall T. Column T4 is fed with liquid and gaseous fractions via lines 62 and 64 respectively. The rectification products of column T4 are 63 (gaseous heads fraction) and 65 (liquid bottoms fraction) and are fed to column T2' by means of a suitable arrangement of heights.

The interconnected system described above serves to split the column T2' depicted in FIG. 1 into smaller, more easily transported, more efficiently operated and more quickly assembled units.

The process provided by the present invention for removing heavy and light fractions from a hydrocarbon-rich feed fraction, preferably from natural gas, has an energy consumption which corresponds to that of a double column arrangement while eschewing the undesired elevation of pressure between the removal of heavies and lights.

Without further elaboration, it is believed that one skilled in the art can, using the preceding description, utilize the present invention to its fullest extent. The preceding preferred specific embodiments are, therefore, to be construed as merely illustrative, and not limiting of the remainder of the disclosure in any way whatsoever.

The preceding examples can be repeated with similar success by substituting the generally or specifically described reactants and/or operating conditions of this invention for those used in the preceding examples.

From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention and, without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions.

The entire disclosures of all applications, patents and publications, cited herein and of corresponding German patent application DE 10 2013 013 883.5, filed Aug. 20, 2013, are incorporated by reference herein.

A process for removing heavies and lights from a hydrocarbon-rich feed fraction, preferably from natural gas, said process comprising:

a) partially condensing (E1, E2) said feed fraction (1),
b) rectificatorily removing a heavies-rich liquid fraction (8) in a 1st removal stage (T1),
c) partially condensing (E4) the resultant, heavies-depleted gas fraction (10), and
d) rectificatorily separating said heavies-depleted gas fraction (10) into a methane-rich liquid fraction (11) and a lights-rich gas fraction (12) in a 2nd removal stage (T2),
e) wherein the 1st removal stage (T1) is operated at a pressure of at least 25 bar,
f) wherein said heavies-depleted gas fraction (10) does not undergo pressure elevation before being fed into the 2nd removal stage (T2),
g) wherein reflux for the 2nd removal stage (T2) is produced via an open loop refrigeration cycle,
h) wherein the refrigerant circulating in said open loop refrigeration cycle is vaporized to two different temperature levels against reflux streams (14, 15) in head condenser (E7) and a side condenser (E8) of the 2nd removal stage (T2), and
i) wherein the pressure of the refrigerant (25) vaporized in said side condenser (E8) is at least three times the pressure of the refrigerant (22) vaporized in said head condenser (E7).

2. The process according to claim 1, wherein said 2nd removal stage (T2) is realized in a column having a dividing wall (T), wherein the dividing wall (T) is at least disposed in that region of the column where the column is fed with said heavies-depleted gas fraction (10) and where a carbon dioxide-lean fraction (25), which is admixed to the open loop refrigeration cycle, is withdrawn.

3. The process according to claim 1, wherein the refrigerant of the open loop refrigeration cycle has a methane content of at least 80 mol %, preferably at least 85 mol %.

4. The process according to claim 2, wherein the composition of the refrigerant of the open loop cooling cycle corresponds essentially to the composition of the carbon dioxide-lean fraction (25) withdrawn from the 2nd removal stage (T2).

5. The process according to claim 1, wherein said 1st removal stage is operated at a pressure of at least 28 bar.

6. The process according to claim 1, wherein the pressure of refrigerant (25) vaporized in said side condenser (E8) is at least five times the pressure of refrigerant (22) vaporized in said head condenser (E7).

7. The process according to claim 1, wherein the pressure of the hydrocarbon-rich feed fraction (1) is more than 50 bar, and said feed fraction (1) is expanded in at least two stages (X1, X2) before being fed into said 1st removal stage (T1).

8. The process according to claim 1, wherein a substream of said heavies-depleted gas fraction (10) obtained in said 1st removal stage (T1) is at least temporarily admixed (50) with the methane-rich liquid fraction (11) obtained in said 2nd removal stage (T2).

9. A process according to claim 1, wherein said hydrocarbon-rich feed fraction is natural gas.

10. The process according to claim 1, wherein the refrigerant of the open loop refrigeration cycle has a methane content of at least 85 mol %.

11. The process according to claim 1, wherein the pressure of the hydrocarbon-rich feed fraction (1) is between 35 and 50 bar, and said feed fraction (1) is expanded in a single stage (X1) before being fed into said 1st removal stage (T1).
12. The process according to claim 1, wherein said methane-rich liquid fraction (11) is expanded (V7) to a pressure from 3 to 15 bar below the operating pressure of said 1st removal stage (T1).

13. The process according to claim 12, wherein said methane-rich liquid fraction (11) is expanded (V7) to a pressure from 5 to 10 bar below the operating pressure of said 1st removal stage (T1).

14. The process according to claim 2, wherein the carbon dioxide concentration in said carbon dioxide-lean fraction (25) is below 50 ppm.

15. The process according to claim 2, wherein the carbon dioxide concentration in said carbon dioxide-lean fraction (25) is below 5 vppm.

16. The process according to claim 4, wherein the carbon dioxide concentration in said carbon dioxide-lean fraction (25) is below 50 ppm.

17. The process according to claim 4, wherein the carbon dioxide concentration in said carbon dioxide-lean fraction (25) is below 5 vppm.

18. The process according to claim 1, wherein said lights-rich gas fraction (12) has a nitrogen content of more than 90 mol %.

19. The process according to claim 18, wherein said lights-rich gas fraction (12) has a nitrogen content of more than 95 mol %.

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