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(54) **METHOD FOR LIQUEFYING A HYDROCARBON-RICH FRACTION**

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(57) **ABSTRACT**

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A process for liquefying a hydrocarbon-rich fraction, in particular natural gas, where the hydrocarbon-rich fraction is pre-cooled and subjected to water separation and a subsequent drying process before liquefaction and the hydrocarbon-rich fraction is liquefied against at least one mixed refrigerant circuit, where the refrigerant circulating in the mixed refrigerant circuit is compressed in at least two stages, subsequently at least partially condensed and the liquid fraction formed here is at least partly mixed into the refrigerant which has been compressed to an intermediate pressure is described. A substream of the liquid fraction serves for pre-cooling the hydrocarbon-rich fraction to be liquefied before it is fed to the water separation, where heat exchange between the liquid fraction and the hydrocarbon-rich fraction to be liquefied is effected by means of at least one heat exchanger system.

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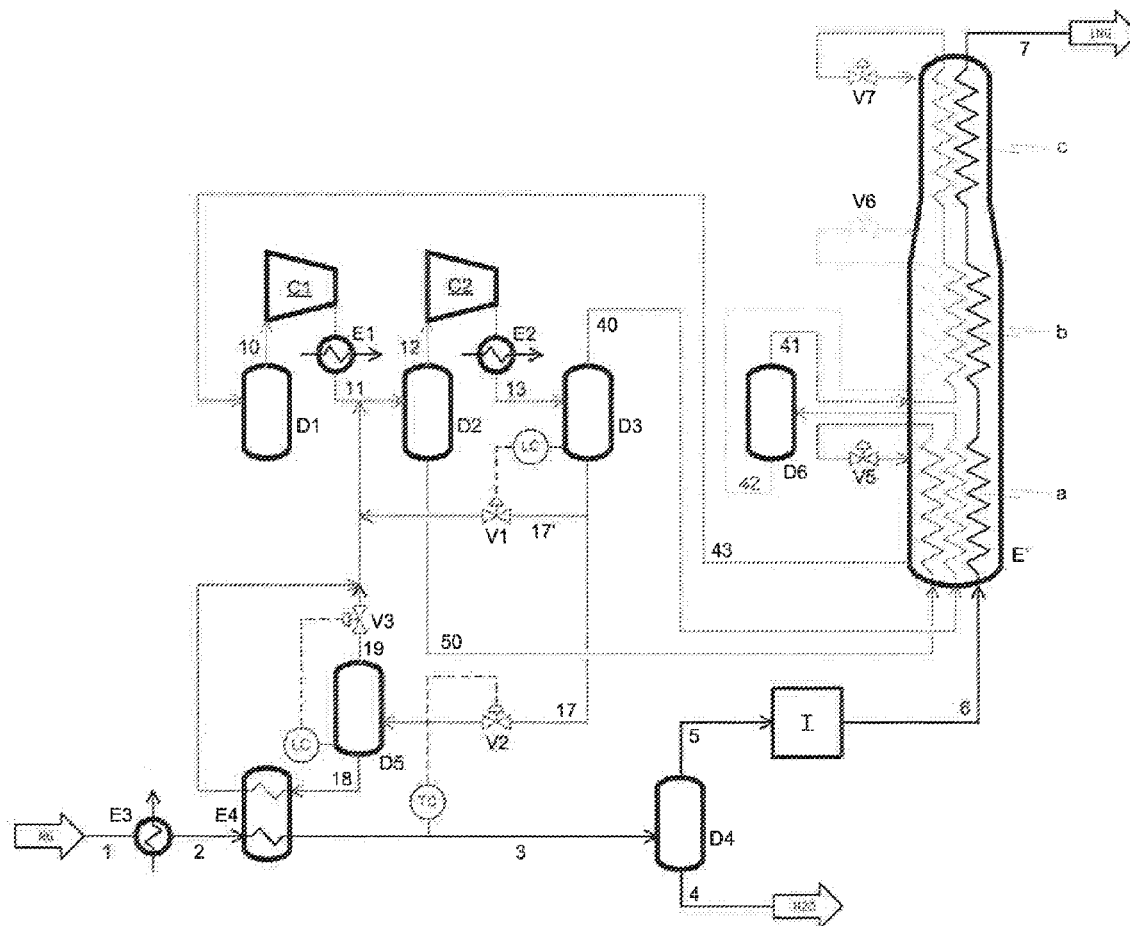
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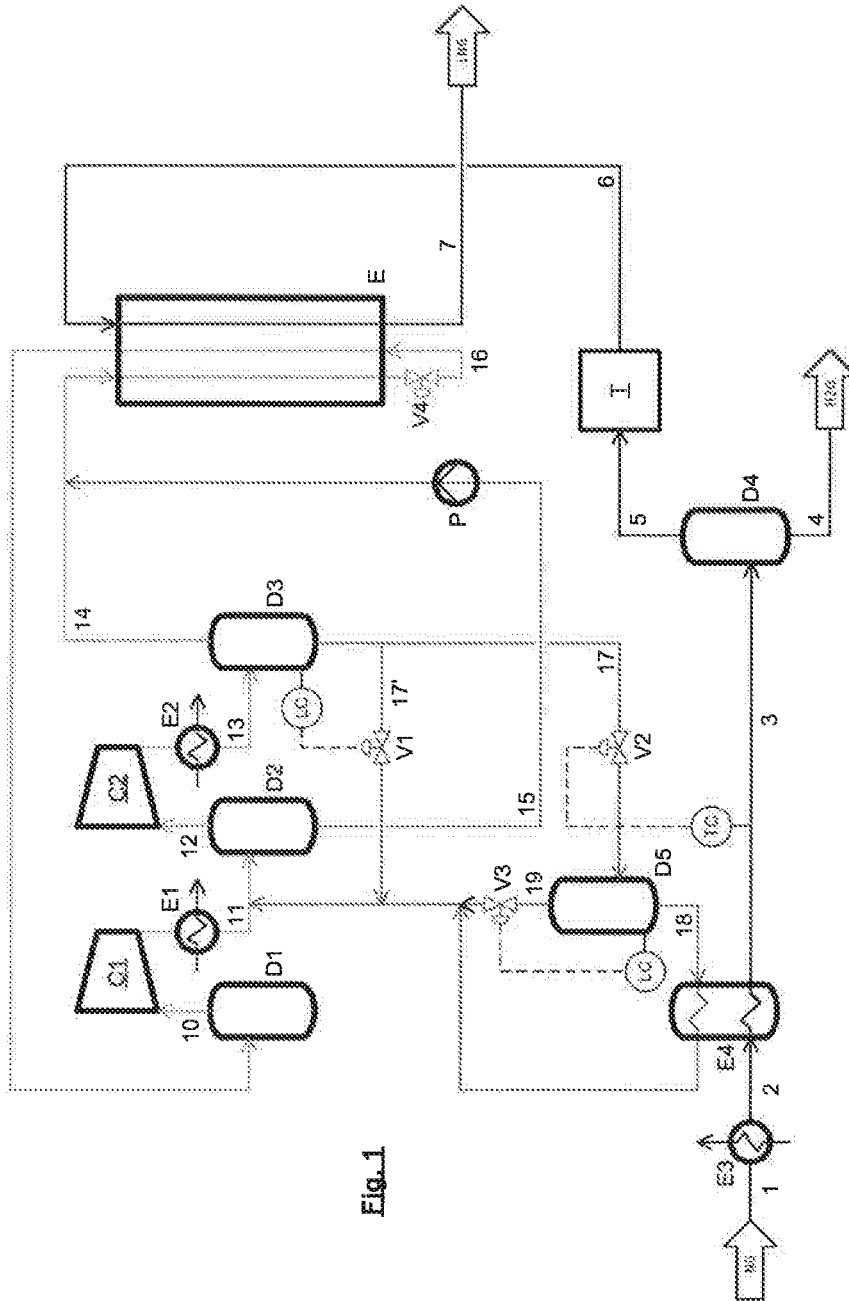


Fig. 1

METHOD FOR LIQUEFYING A HYDROCARBON-RICH FRACTION

[0001] The invention relates to a process for liquefying a hydrocarbon-rich fraction, in particular natural gas, where

[0002] the hydrocarbon-rich fraction is precooled and subjected to water separation and a subsequent drying process before liquefaction and

[0003] the hydrocarbon-rich fraction is liquefied against at least one mixed refrigerant circuit,

[0004] where the refrigerant circulating in the mixed refrigerant circuit is compressed in at least two stages, subsequently at least partially condensed and the liquid fraction formed here is at least partly mixed into the refrigerant which has been compressed to an intermediate pressure.

[0005] To liquefy hydrocarbon-rich gas fractions, in particular natural gas, use is made of, inter alia, processes employing a refrigerant mixture consisting of light hydrocarbons and nitrogen, with the refrigerant mixture being at least partially condensed at elevated pressure compared to the surroundings. In order to liquefy natural gas, the liquid refrigerant is subsequently vaporized under reduced pressure by indirect heat exchange with the natural gas. Since, in the case of a (non-azeotropic) mixture, the dew point at a given pressure is always above the boiling point, the refrigerant evaporation takes place, depending on the composition, gradually over a temperature range which extends, depending on the process, over at least 20° C., sometimes even over 200° C.

[0006] If the capital costs for a natural gas liquefaction plant are to be kept low, a mixture circuit of the above-described type is used exclusively for the entire temperature range from ambient temperature to LNG (Liquefied Natural Gas) product temperature (about -160° C.). The use of a separate precooling circuit for the temperature range from ambient temperature to about -50° C. is dispensed with here.

[0007] In a procedure of this type, which is usually referred to as SMR (Single Mixed Refrigerant) process, only one refrigerant, or substreams thereof, which displays gradual evaporation is thus available. Such a natural gas liquefaction process is known, for example, from DE 19722490.

[0008] Before liquefaction, the natural gas is generally freed of acidic gas components, such as CO₂ and H₂S, by means of a chemical scrub, for example an amine scrub. As a result, the natural gas is saturated with water (vapor). In order to achieve an economical design of the subsequent drying, which is generally based on adsorption on a zeolitic molecular sieve, the natural gas is cooled as far as possible and the water concentration is reduced by partial water condensation and subsequent water separation to such an extent that a limit is imposed on the threshold formation of hydrates or water ice. This limit is, depending on the gas composition, attained at a temperature of up to 20° C.

[0009] Under many climatic conditions, it is not possible to cool the natural gas to sufficiently close (not more than 10° C., preferably 5° C., above the hydrate temperature) to the abovementioned limit temperature against air and/or cooling water.

[0010] Mixed refrigerants are, owing to the gradual evaporation, not very suitable for very precisely attaining the optimum temperature of the moist natural gas before drying

in an economical way without at the same time going below the hydrate temperature at least in parts of the heat exchanger used.

[0011] It is an object of the present invention to provide a process of the type in question for liquefying a hydrocarbon-rich fraction, which makes it possible for the hydrocarbon-rich fraction to be liquefied to be precooled before drying without use of a complete precooling circuit, i.e. without an additional compressor. In particular, the hydrocarbon-rich fraction should be precooled to a temperature of not more than 10° C. above, preferably not more than 5° C. above, the hydrate temperature without the moist hydrocarbon-rich fraction coming into thermal contact with temperatures below the hydrate point.

[0012] To achieve this object, a process of the type in question for liquefying a hydrocarbon-rich fraction, which is characterized in that a substream of the liquid fraction serves for precooling the hydrocarbon-rich fraction to be liquefied before the latter fraction is fed to the water separation, where heat exchange between the liquid fraction and the hydrocarbon-rich fraction to be liquefied is effected by means of at least one heat exchanger system, is proposed.

[0013] In a further embodiment of the process of the invention for liquefying a hydrocarbon-rich fraction, it is proposed that a substream of the liquid fraction of the refrigerant be depressurized to a pressure of at least 0.3 bar above, preferably at least 0.7 bar above, the suction pressure of the second or last compressor stage and only the liquid fraction formed here be used for precooling the hydrocarbon-rich fraction to be liquefied before the latter is fed to the water separation.

[0014] According to the invention, the precooling of the hydrocarbon-rich fraction to be liquefied before this fraction is fed to the water separation is effected against a substream of the liquid fraction formed in the partial condensation of the compressed refrigerant. Here, the heat exchange between this liquid fraction and the hydrocarbon-rich fraction to be liquefied is achieved by means of a heat exchanger system. The heat exchanger system serves to effect indirect heat transfer between the hydrocarbon-rich fraction to be liquefied and the gradually evaporating refrigerant.

[0015] For the purposes of the present invention, the term "heat exchanger system" refers to any system in which indirect heat transfer occurs between at least two media by means of a heat transfer fluid. Such a heat exchanger system is known, for example, from the U.S. Pat. No. 2,119,091.

[0016] Such heat exchanger systems preferably use a boiling pure material which is present in liquid form in the temperature range from 0 to 30° C., which can be, for example, ethane, ethylene, propane, propylene, butane, carbon dioxide or ammonia, as heat transfer fluid.

[0017] The heat exchanger system is preferably made up of two bundles of straight tubes, two helically coiled heat exchangers, two plate exchangers or any combination of these construction types, where the aforementioned heat exchanger components have preferably been installed in a pressure vessel which contains the boiling heat transfer fluid.

[0018] Suitable selection of the pure material heat transfer fluid and regulation of the operating pressure thereof and thus the boiling point thereof enable the hydrocarbon-rich fraction to be cooled to very close to the hydrate temperature without coming directly into thermal contact with an unacceptably cold refrigerant stream. The heat transfer fluid

brings about the desired heat transfer comparatively efficiently by continual condensation on the refrigerant side and evaporation on the side of the hydrocarbon-rich fraction. In contrast to the gradually evaporating mixed refrigerant, the heat transfer fluid operates at constant boiling point and thus dew point. Even if the condensation of the heat transfer fluid occurs at least partially against a mixed refrigerant which vaporizes below the hydrate temperature of the hydrocarbon-rich fraction, the hydrocarbon-rich fraction and the mixed refrigerant are effectively separated thermally by the heat transfer fluid.

[0019] The procedure according to the invention makes it possible for the load on the drying process to be optimally reduced by cooling of the hydrocarbon-rich fraction to be liquefied or of the natural gas to be liquefied down to close to the hydrate point, and also enables water separation.

[0020] The process of the invention for liquefying a hydrocarbon-rich fraction and also further advantageous embodiments thereof are illustrated in more detail by the working examples depicted in FIGS. 1 and 2.

[0021] In the working examples depicted in FIGS. 1 and 2, which differ merely in terms of the actual liquefaction process, the hydrocarbon-rich fraction 1 to be liquefied, which normally has a temperature in the range from 40 to 80° C., is cooled to a temperature in the range from 30 to 60° C. against cooling air and/or cooling water in the heat exchanger E3. The hydrocarbon-rich fraction 2 to be liquefied is subsequently fed to a heat exchanger system E4 and pre-cooled in this to a temperature of not more than 10° C. above, preferably not more than 5° C. above, its hydrate temperature. The hydrocarbon-rich fraction 3 which has been pre-cooled in this way is fed to a separator D4 at the bottom of which the condensed-out water 4 is obtained. The hydrocarbon-rich fraction 5 taken off at the top of the separator D4 is then fed to a drying process T which is depicted merely as a black box. This is normally an adsorption process in which a zeolitic molecular sieve is normally used as adsorbent. The hydrocarbon-rich fraction 6 which is to be liquefied and has been pretreated in this way is subsequently cooled, liquefied and optionally supercooled in the heat exchanger E against the refrigeration circuit yet to be explained, so that, in the case of natural gas liquefaction, an LNG product stream can be taken off via conduit 7.

[0022] The liquefaction of the hydrocarbon-rich fraction occurs against a mixed refrigerant circuit in the working examples depicted in FIGS. 1 and 2. Such mixed refrigerant circuits usually have nitrogen and at least one C₁₊-hydrocarbon as refrigerant. The refrigerant 10 to be compressed is compressed to an intermediate pressure in the first compressor stage C1. The compressed refrigerant 11 is subsequently partially condensed in the after-cooler E1 and separated in the separator D2 into a relatively low-boiling gas fraction 12 and a relatively high-boiling liquid fraction 15. Only the lower-boiling gas fraction 12 is compressed to the maximum circuit pressure in the second compressor stage C2. The compressed refrigerant 13 is again partially condensed in the after-cooler E2 and separated in the separator D3 into a gas fraction 14 and a liquid fraction 17/17'. In the working example depicted in FIG. 1, the gas fraction 14 and the abovementioned, relatively high-boiling refrigerant liquid fraction 15, which is pumped by means of the pump P to the pressure of the refrigerant gas fraction 14, are together cooled against themselves in the heat exchanger E and subsequently depressurized in the depressurization valve V4

in order to provide refrigeration. The refrigeration-providing depressurized refrigerant 16 is then completely vaporized in the heat exchanger E against the hydrocarbon-rich fraction 6 to be liquefied and is again fed to the separator D1 located upstream of the first compressor stage C1; this serves to secure the compressor stage C1 since liquid fractions which may be entrained therein are separated off.

[0023] Whereas the refrigerant liquid fraction 17' taken off from the separator D3 is entirely recirculated via the depressurization valve V1 to a point upstream of the separator D2 in the methods of the prior art, a substream 17 of this liquid fraction is now employed for precooling the hydrocarbon-rich fraction 1/2 to be liquefied. For this purpose, the above-described substream 17 of the liquid fraction is depressurized in the valve V2, preferably to a pressure of at least 0.3 bar above, in particular at least 0.7 bar above, the suction pressure of the second compressor stage C2, and the resulting two-phase stream is fed to the separator D5. The gas fraction 19 present therein is recirculated via the regulating valve V3 to a point upstream of the separator D2, while the liquid fraction 18 obtained in the separator D5 is employed for precooling the hydrocarbon-rich fraction 1/2 to be liquefied and the liquid fraction 18 is subsequently likewise recirculated to a point upstream of the separator D2.

[0024] Heat exchange between the liquid fraction 17 or the liquid fraction 18 obtained after depressurization in the valve V2 and the hydrocarbon-rich fraction 1/2 to be liquefied is effected by means of the heat exchanger system E4.

[0025] In the working example depicted in FIG. 2, the relatively high-boiling liquid fraction 50 of the refrigerant which has been taken off from the separator D2 and the refrigerant gas fraction 40 which has been taken off from the separator D3 are cooled separately in the precooling zone a of the heat exchanger E'. While the relatively high-boiling liquid fraction 50 is depressurized in the valve V5 to provide refrigeration and subsequently vaporized in countercurrent to the hydrocarbon-rich fraction 6 to be liquefied, the abovementioned gas fraction 40 is partially condensed and separated in the separator D6 into a further gas fraction 41 and a further liquid fraction 42. The gas fraction 41 is cooled and partially condensed in the liquefaction and supercooling zones b and c of the heat exchanger E'. It is subsequently depressurized in the depressurization valve V7 to provide refrigeration and completely vaporized in countercurrent to the hydrocarbon-rich fraction 6 which is to be liquefied and optionally to be supercooled. The liquid fraction 42 obtained in the separator D6 is cooled further in the liquefaction zone b of the heat exchanger E', depressurized in the depressurization valve V6 to provide refrigeration and completely vaporized in countercurrent to the hydrocarbon-rich fraction 6 to be liquefied. If the heat exchanger E' depicted in FIG. 2 is configured as a so-called helically coiled heat exchanger, evaporation of the abovementioned refrigerant streams 41, 42 and 50 occurs in the outer jacket of the helically coiled heat exchanger. The refrigerant streams 41, 42 and 50 which have been combined in the heat exchanger E' and completely vaporized therein are fed via conduit 43 to the separator D1 located upstream of the first compressor stage C1.

1. A process for liquefying a hydrocarbon-rich fraction where

the hydrocarbon-rich fraction is pre-cooled and subjected to water separation and a subsequent drying process before liquefaction and

the hydrocarbon-rich fraction is liquefied against at least one mixed refrigerant circuit,
where the refrigerant circulating in the mixed refrigerant circuit is compressed in at least two stages, subsequently at least partially condensed and the liquid fraction formed here is at least partly mixed into the refrigerant which has been compressed to an intermediate pressure,
characterized in that a substream of the liquid fraction serves for precooling the hydrocarbon-rich fraction to be liquefied before it is fed to the water separation, where heat exchange between the liquid fraction and the hydrocarbon-rich fraction to be liquefied is effected by means of at least one heat exchanger system.

2. The process as claimed in claim 1, characterized in that the substream of the liquid fraction is depressurized to a pressure of at least 0.3 bar above, the suction pressure of the second or last compressor stage and only the liquid fraction formed here serves for precooling the hydrocarbon-rich fraction to be liquefied before it is fed to the water separation.
3. The process as claimed in claim 1, characterized in that a boiling pure material which is present in liquid form in the

temperature range from 0 to 30° C., is used as heat transfer fluid of the heat exchanger system.

4. The process as claimed in claim 1, characterized in that the heat exchanger system is made up of two bundles of straight tubes, two helically coiled heat exchangers, two plate exchangers or any combination of these construction types, where the heat exchanger components have preferably been installed in a pressure vessel which contains the boiling heat transfer fluid.

5. The process as claimed in claim 1, characterized in that the refrigerant circulating in the mixed refrigerant circuit comprises nitrogen and at least one C₁₊-hydrocarbon.

6. The process as claimed in claim 1 wherein the hydrocarbon-rich fraction is natural gas.

7. The process as claimed in claim 2 wherein the substream of the liquid fraction is depressurized to a pressure of at least 0.7 bar above the suction pressure of the second or last compressor stage.

8. The process as claimed in claim 3 wherein the boiling pure material is selected from the group consisting of ethane, ethylene, propane, propylene, butane, carbon dioxide and ammonia.

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