PROCESS FOR RELIQUIFYING A METHANE-RICH FRACTION

A process for reliquifying a methane-rich fraction, in particular boil-off gas, is described. In this process,

a) a methane-rich fraction is compressed to a pressure at least 20% above the critical pressure of the fraction to be compressed,
b) liquefied and supercooled,
c) depressurized to a pressure in the range from 5 to 20 bar,
d) separated into a gaseous nitrogen-rich fraction and a liquid nitrogen-depleted fraction,
e) the nitrogen-depleted fraction is depressurized to a pressure in the range from 1.1 to 2.0 bar,
f) the gaseous fraction obtained, without being warmed and
compressed, is mixed into the methane-rich fraction, and

g) the liquid product fraction obtained in the depressurization of the low-nitrogen fraction has a nitrogen content of ≤1.5 mol %.
PROCESS FOR RELIQUEFYING A METHANE-RICH FRACTION

[0001] The invention relates to a process for reliquefying a methane-rich fraction, in particular boil-off gas.

[0002] In the following, the term “boil-off gas” refers both to boil-off gases and also to gas mixtures which have a similar composition; displacement gases which arise, for example, in the loading of LNG into transport tanks on ships or goods vehicles may be mentioned merely by way of example.

[0003] In the liquefaction of methane-rich gases or boil-off gases, appropriate measures for discharging a nitrogen-rich fraction are required above a certain nitrogen content in order to limit the nitrogen content of the liquefied natural gas (LNG) to usually 1 mol%.

[0004] U.S. Pat. No. 5,036,671 discloses a method of discharging a nitrogen-rich fraction, in which gas streams which have a significantly increased content of nitrogen compared to the crude gas are taken off at the cold end of the liquefaction process via one or more separators. These gas streams are generally compressed, optionally partly recirculated to the crude gas and usually used as fuel gas. In the liquefaction process described in U.S. Pat. No. 5,036,671, the boil-off gas flowing from the LNG tank located downstream of the liquefaction process is warmed and compressed at approximately ambient temperature.

[0005] Since the operating pressure in such LNG tanks is normally only slightly, typically 50 mbar, above ambient pressure, there is a high probability of generating subatmospheric pressure in the compressor in the warm-intake compression of the boil-off gas. This can lead to entry of air and thus oxygen and thus represent a safety risk.

[0006] It is an object of the present invention to propose a process of the type in question for reliquefying a methane-rich fraction, which avoids the abovementioned disadvantages.

[0007] To achieve this object, a process of the type in question for reliquefying a methane-rich fraction, in which

[0008] a) the methane-rich fraction is compressed to a pressure which is at least 20% above the critical pressure of the fraction to be compressed,

[0009] b) liquefied and supercooled,

[0010] c) depressurized to a pressure in the range from 5 to 20 bar,

[0011] d) separated into a gaseous nitrogen-rich fraction and a liquid nitrogen-depleted fraction,

[0012] e) the nitrogen-depleted fraction is depressurized to a pressure in the range from 1.1 to 2.0 bar,

[0013] f) where the gaseous fraction obtained is, without being warmed and compressed, mixed into the methane-rich fraction,

[0014] g) the liquid product fraction obtained in the depressurization of the low-nitrogen fraction has a nitrogen content of ≤ 1.5 mol%, is proposed.

[0015] If the liquefaction and supercooling of the methane-rich fraction are carried out against at least one refrigerant circuit and/or at least one refrigerant mixture circuit and this/these has/have at least one circuit compressor the pressure to which the methane-rich fraction is compressed, the pressure to which the liquefied and supercooled methane-rich fraction is depressurized and the temperature to which the methane-rich fraction is cooled are selected or varied according to the invention in such a way that

[0016] the drive power of the compressor used for compressing the methane-rich fraction and the drive power of the circuit compressor(s) are shifted relative to one another without the total power changing by more than ± 5% or

[0017] the drive power of the compressor used for compressing the methane-rich fraction and the drive power of the circuit compressor(s) are shifted relative to one another in such a way that a division of the total power in a range from 30/70 to 70/30 is achieved.

[0018] Further advantageous embodiments of the process of the invention for reliquefying a methane-rich fraction, which are subject matter of the dependent claims, are characterized in that

[0019] the methane-rich fraction is compressed to a pressure which is at least 30% above the critical pressure of the fraction to be compressed,

[0020] the liquefied and supercooled methane-rich fraction is depressurized to a pressure in the range from 7 to 15 bar and/or

[0021] the nitrogen-depleted fraction is depressurized to a pressure in the range from 1.2 to 1.8 bar.

[0022] The process of the invention for reliquefying a methane-rich fraction and also further advantageous embodiments of this process will be illustrated below with the aid of the example shown in FIG. 1.

[0023] The methane-rich fraction 1 to be reliquefied is compressed in the single-stage or multistage compressor unit C1 to a pressure which is at least 20%, preferably at least 30%, above the critical pressure of the methane-rich fraction 1 to be reliquefied. In this way, two-phase streams of the methane-rich fraction 1 to be reliquefied are avoided in the heat exchanger(s) of the subsequent liquefaction stage.

[0024] According to the invention, the methane-rich fraction 1 to be reliquefied is not warmed before being compressed in C1. Owing to the compression in C1, the methane-rich fraction to be reliquefied is heated to a temperature above that of the surroundings, and it is therefore cooled to approximately ambient temperature against cooling water or air in the heat exchanger E1.

[0025] In the heat exchanger E2, the compressed methane-rich fraction 2 is cooled to a temperature in the range from -100 to -140°C, preferably from -110 to -130°C, and thereby liquefied and supercooled.

[0026] The cooling of the compressed methane-rich fraction can in principle be carried out against any refrigerant circuit or refrigerant mixture circuit or combinations of these. The refrigerant mixture circuit shown in FIG. 1 is merely one of the many possible variants. The heat exchanger E2 shown in FIG. 1 can in reality be formed by a plurality of separate heat exchangers and/or heat exchanger sections. It is preferably configured as helically coiled heat exchanger having two bundles or as soldered plate exchanger.

[0027] After liquefaction and supercooling, the methane-rich fraction 3 taken off from the heat exchanger E2 is depressurized in the valve V1 to a pressure in the range from 5 to 20 bar, preferably from 7 to 15 bar. The gaseous, nitrogen-rich fraction 4 obtained here is taken off at the top of the separator D1 located downstream of the valve V1, warmed in the heat exchanger E2 against the methane-rich fraction 2 to be cooled, with this warming being optional. The warmed nitrogen-rich fraction 5 is, if desired, subsequently compressed in one or more stages C2 and passed via line 6 to further use, for example as fuel. This nitrogen-rich gas 5 preferably has a pressure in the range from 5 to 20 bar, in particular from 7 to 15 bar. It is thus, for example, directly suitable for firing
steam-generating boilers. When used as fuel gas in gas turbines, the outlay for compression is significantly reduced compared to the prior art in which the initial pressure is a lower tank pressure.

[0028] The liquid nitrogen-depleted fraction 7 obtained in the separator D1 after depressurization is depressurized in the valve V2 to a pressure in the range from 1.1 to 2.0 bar, preferably from 1.2 to 1.8 bar. The gaseous fraction obtained in this depressurization is taken off via line 8 from the top of the separator D2 and, without warming, mixed into the methane-rich fraction 1 to be compressed. The liquid fraction obtained at the bottom of the separator D2 represents the liquefied natural gas product (LNG); this has a nitrogen content of ≤1.5 mol %.

[0029] Owing to the cold intake of the fractions or gas mixtures 1 and 8 to be compressed in the compressor stage C1, the safety risk mentioned at the outset which exists in the case of warm-intake compression of boil-off gases can be effectively prevented. Undesirable and dangerous entry of air and thus oxygen into the compressor C1 is thus ruled out.

[0030] Owing to the recirculation of the gaseous fraction 8 obtained after the second decompression V2 to the methane-rich fraction 1 to be compressed, the amount of LNG product can be increased, which is advantageous in terms of costs, and the total energy consumption can be reduced.

[0031] A process alternative which is not shown in FIG. 1 is to replace the separator D1 by a stripper. In this, the methane-rich fraction 3 which has been depressurized in the valve V1 is stripped of nitrogen from below by a fraction of the methane-rich fraction 2 to be cooled over suitable internals such as packing and/or trays. As the required stripping gas, a propylene in the methane-rich fraction 2 to be cooled is drawn in either between the heat exchangers E1 and E2 or, in an embodiment as helically coiled heat exchanger having two bundles, between the bundles.

[0032] As mentioned above, cooling and liquefaction of the methane-rich fraction 2 is effected in the heat exchanger E2 against a refrigerant mixture circuit shown merely by way of example. The refrigeration mixture is, after warming and vaporization in the heat exchanger E2 against the methane-rich fraction 2 to be cooled, conveyed via line 10 into a separator D3 located upstream of a two-stage compressor unit C3. This is in the interests of the safety of the compressor unit C3, since liquid particles entrained in the refrigerant mixture precipitate therein.

[0033] The refrigerant mixture to be compressed is conveyed from the top of the separator D3 via line 11 to the compressor unit C3 and compressed in the first stage thereof to an intermediate pressure. After cooling in the intermediate cooler E3, the refrigerant mixture which has been compressed to the intermediate pressure is fed via line 12 to a second separator D4. The relatively low-boiling refrigerant mixture fraction taken off from the top of the latter is fed via line 13 to the second compressor stage of the compressor unit C3 and compressed in this to the desired final pressure. This refrigerant mixture fraction is subsequently cooled in the aftercooler E4 and fed via line 15 to a third separator D5.

[0034] The liquid fraction obtained in this separator D5 is recirculated via line 16 and valve V3 to a point upstream of the second separator D4. The relatively low-boiling refrigerant mixture fraction taken off from the top of the third separator D5 via line 17 is, after mixing with the liquid relatively high-boiling refrigerant mixture fraction 14 taken off from the bottom of the second separator D4, conveyed via line 18 through the heat exchanger E2 in order to be able to “bridge” the pressure differences in the lines 14 and 17, a pump P is provided in the line 14.

[0035] The refrigeration mixture 18 which has been cooled, liquefied and supercooled against itself in the heat exchanger E2 is, after having been taken off from the heat exchanger E2, depressurized in the valve V4 so as to generate cold and subsequently conveyed via line 19 through the heat exchanger E2 again in countercurrent to the methane-rich fraction 2 to be liquefied.

[0036] In the process of the invention for liquefying a methane-rich fraction, the powers of the feed gas compressor C1 and of the refrigeration circuit compressor C3 can be shifted relative to one another by suitable choice of the pressures downstream of the compressor unit C1 and the valve V1 and of the temperature of the cooled methane-rich fraction 3 before depressurization in the valve V1, thereby to allow the total power being appreciably, meaning an increase or decrease of ≤5%, changed.

[0037] It is possible, advantageously, to adapt the required powers of the drives A and B of the compressors/compressor units C1 and C3 to such an extent that drives (gas turbines, steam turbines and/or electric motors) having the same power can be used. This simplification is of great economic advantage. Such a redistribution of the drive powers of the feed gas compressor C1 and the refrigeration circuit compressor C3 is neither known from the prior art nor rendered obvious thereby.

[0038] The amount of gas taken off at the top of the separator D1 can be kept constant by varying the pressure in the separator D1. This results in a variable amount of gaseous fraction 8 which is recirculated from the separator D2 to the suction side of the feed gas compressor C1.

[0039] As mentioned, a preferred redistribution between the compressor/compressor units C1 and C3 leads to equal drive powers. Instead of this 50/50 solution, any other distribution in the range from 30/70 to 70/30 can be achieved. The solution preferred in each case depends, for example, on the power steps of customary drives (gas turbines).

1. Process for liquefying a methane-rich fraction, in particular boil-off gas, wherein
   a) the methane-rich fraction (1) is compressed (C1) to a pressure which is at least 20% above the critical pressure of the fraction to be compressed,
   b) liquefied and supercooled (E2),
   c) depressurized (V1) to a pressure in the range from 5 to 20 bar and
   d) separated into a gaseous nitrogen-rich fraction (4) and a liquid nitrogen-depleted fraction (7) and
   e) the nitrogen-depleted fraction (7) is depressurized (V2) to a pressure in the range from 1.1 to 2.0 bar,
   f) where the gaseous fraction (8) obtained is, without being warmed and compressed, mixed into the methane-rich fraction (1) and
   g) the liquid product fraction (9) obtained in the depressurization of the low-nitrogen fraction has a nitrogen content of ≤1.5 mol %.

2. Process according to claim 1, wherein the liquefaction and supercooling (E2) of the methane-rich fraction (1) is carried out against at least one refrigerant circuit and/or at least one refrigerant mixture circuit and this/have at least one circuit compressor (C3), characterized in that the pressure to which the methane-rich fraction (1) is compressed (C1), the pressure to which the liquefied and supercooled methane-rich
fraction (3) is depressurized (V1) and the temperature to which the methane-rich fraction (2) is cooled are selected or varied in such a way that
the drive power of the compressor (C1) used for compressing the methane-rich fraction (1) and the drive power of the circuit compressor(s) (C3) are shifted relative to one another without the total power changing by more than ±5% or
the drive power of the compressor (C1) used for compressing the methane-rich fraction (1) and the drive power of the circuit compressor(s) (C3) are shifted relative to one another in such a way that a division of the total power in the range from 30/70 to 70/30 is achieved.

3. Process according to claim 1, characterized in that the methane-rich fraction (1) is compressed (C1) to a pressure which is at least 30% above the critical pressure of the fraction to be compressed.

4. Process according to claim 1, characterized in that the liquefied and supercooled methane-rich fraction (3) is depressurized (V1) to a pressure in the range from 7 to 15 bar.

5. Process according to claim 1, characterized in that the nitrogen-depleted fraction (6) is depressurized (V2) to a pressure in the range from 1.2 to 1.8 bar.