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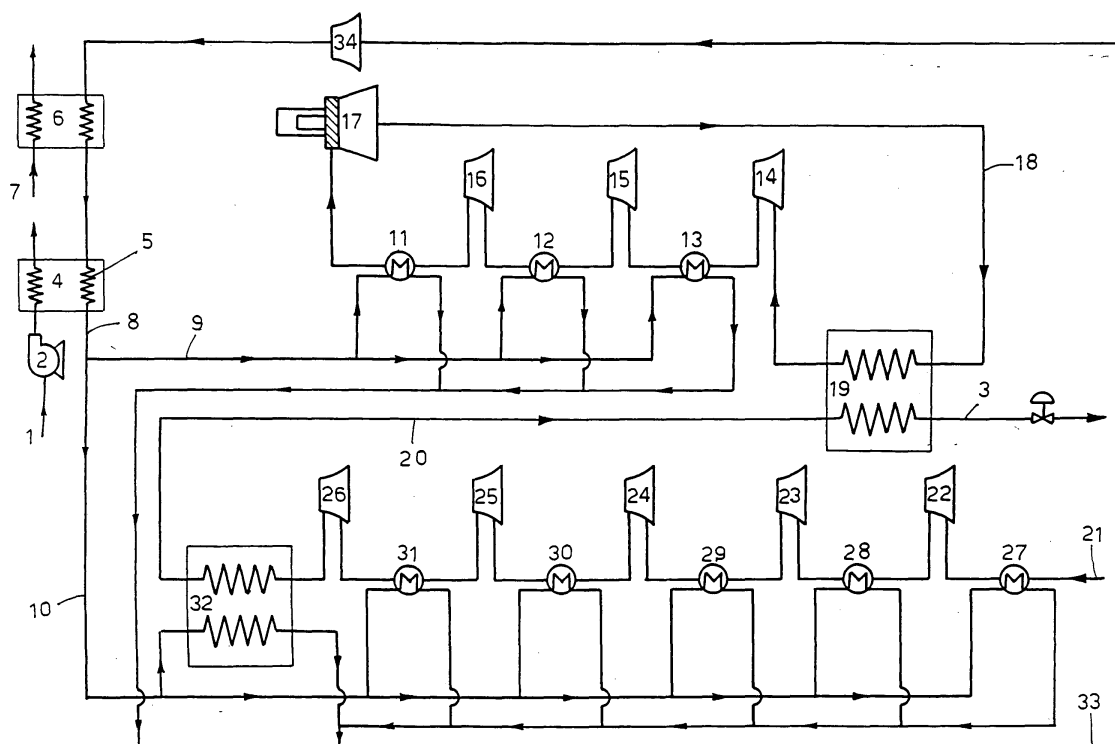
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(54) **Process for nitrogen liquefaction by recovering the cold derived from liquid methane gasification**

(57) This process for nitrogen liquefaction by recovering the cold derived from liquid methane gasification has the characteristic of cooling with the liquid methane (1) a cryogenic fluid (5), preferably nitrogen, and then using said cryogenic fluid as coolant fluid (9,10) in two nitrogen compressor units of the nitrogen liquefier, both

for the interstage coolers (11,12,13,27,28,29,30,31,32) and for the intake coolers (27) and for the final delivery coolers (19,32) of one of the nitrogen compressor unit.

The use of nitrogen cooled by the methane enables liquid nitrogen to be produced (3) in a liquefier consisting of the two said compressor units and a cryogenic turbine (17), with a very low specific energy consumption.



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Description

[0001] This invention relates to a process for recovering the cold deriving from liquid methane gasification.

[0002] As methane has to be obtained from many regions of the world, it is not always possible to use usual methane pipelines, and instead methane tankers specialized for this purpose have to be used.

[0003] To be able to transport the maximum quantity of methane, these tankers are designed to transport it in liquid form in order to reduce its volume. However to remain in the liquid state, the methane has to be maintained at cryogenic temperature, the value of which depends on the storage pressure (for example -154°C at 2 bar absolute).

[0004] In methane tankers the methane is contained in suitable tanks under high thermal insulation (using the Dewar flask principle).

[0005] On reaching land, this methane has to be transported or used in gaseous form, and must therefore be vaporized and heated. To express this concept in other words, it could be said that in order to undergo vaporization and heating, it must transfer its "cold" to another fluid, which hence itself becomes cold during said heat transfer.

[0006] In this respect, it is known that to cool a gas to a temperature less than the temperature of the environment in which it is present requires considerable energy consumption related to the application of usual thermodynamic refrigeration cycles.

[0007] Substantially, this energy consumption is imposed by the need to compress the gas to be liquefied so that it becomes hot, and then to extract from it the heat associated with the temperature increase deriving from this compression more efficiently as it is effected at a higher temperature level. Subsequent expansion of the compressed and cooled gas in a turbine further reduces its temperature to cryogenic values, with resultant liquefaction of the gas.

[0008] Hence on this basis, liquid methane transported by methane tankers contains a "negative energy" or cold, which it would be extremely advantageous to recover.

[0009] In this respect, one of the usual methods of heating liquid methane is to pass the liquid methane through a heat exchanger through which water circulates in counter-current to heat said methane from a temperature of -150°C to a temperature of +15°C.

[0010] Besides not providing any energy recovery, this gasification method alters the ecosystem as it causes artificial intermittent cooling of the sea.

[0011] This is because the water used to heat the methane is withdrawn from the sea, cooled and then returned to the sea at a temperature lower than that at which it was withdrawn.

[0012] Because of the progressive importance assumed by methane traffic, current research is aimed at recovering the cold possessed by liquid methane in liquid

air production cycles (Linde machine, Claude machine).

[0013] These cycles consist of repeated compression, cooling and expansion until the air becomes liquid at a temperature of -195°C.

[0014] More specifically, the known art uses the said cold mainly during cooling by suitable heat exchangers.

[0015] However this known art does not provide a technical basis suitable for using the said cold offered by liquid methane in a manner able to reduce the energy consumption relating to the cooling and liquefaction of technical gases normally used in industry (nitrogen, oxygen, argon).

[0016] To illustrate these concepts with numerical examples, expressive of current industrial reality, 13,000 kWh are required to liquefy 25,000 Normal (atmospheric pressure, 0°C) cubic metres of nitrogen.

[0017] If the cold yielded by liquid methane during its gasification or expansion to ambient temperature is used with current techniques, this energy consumption is reduced to only 8,400 kWh, hence saving 4,600 kWh.

[0018] This is evidently a considerable saving, but which could be better utilized if a method could be found for using the said cold to liquefy industrial gases in a more direct manner within the liquefaction process.

[0019] An object of the present invention is to define a process for using the cold deriving from liquid methane gasification which is more advantageous than those currently used.

[0020] This and other objects which will be more apparent hereinafter will be seen to have been attained on reading the ensuing description of a process for recovering the cold deriving from liquid methane gasification characterised by cooling with the liquid methane a cryogenic fluid, preferably nitrogen, then using said cryogenic fluid as the cooling fluid in two nitrogen compressor units of a liquefier, both for the interstage coolers and for the intake and final delivery coolers.

[0021] Nitrogen, assuming that to be the cryogenic fluid compressed by a first of said compressor units, is liquefied in a heat exchanger by further nitrogen circulating in closed cycle which is continuously compressed by a second compressor unit and then expanded in a cryogenic turbine to achieve final cooling to a temperature of -190°C. The nitrogen cooled by the turbine in this manner is used to cool all the nitrogen compressed by the first compressor unit until a temperature of -180°C is attained, at which the nitrogen liquefies. The liquid nitrogen produced in this manner is then used in the air fractionation plant to produce liquid oxygen, nitrogen and argon, and for all other possible uses of liquid nitrogen.

[0022] The invention is illustrated by way of non-limiting example in the accompanying drawing, which shows a general scheme of a plant for implementing the process.

[0023] With reference to said drawing, a liquid methane inlet line 1 leads to a pump 2. The pump 2 (indica-

tively of centrifugal type) feeds the liquid methane to a heat exchanger 4, which subtracts heat from a line 5 through which nitrogen passes in counter-current.

[0024] This nitrogen originates from another heat exchanger 6 in which a water line 7 had previously raised its temperature from about -98°C to about -34°C.

[0025] Said nitrogen is maintained at a relatively high pressure to increase the temperature difference between the methane and nitrogen in order, other conditions being equal, to achieve greater absorption of the cold provided by the liquid methane.

[0026] The nitrogen cooled in this manner by heat transfer with liquid methane leaves the heat exchanger 4 through a line 8, which branches into two lines 9 and 10 to enable the cold of the nitrogen to be used to cool the nitrogen circulating within specific circuits 16, 20 of the apparatus in which said nitrogen is liquefied.

[0027] More precisely, the line 9 conveys the cold withdrawn from the methane to the interstage coolers (heat exchangers) 11, 12, 13 located respectively at the outlet of three stages 16, 15, 14 of a conventional compressor unit for the nitrogen in the circuit 18, which is of closed type.

[0028] At the outlet of the interstage cooler 11 the nitrogen of the closed circuit 18, cooled in this manner, has a pressure of about 10 bar and a temperature of about -141°C.

[0029] In this state it is expanded through a conventional cryogenic turbine 17 by which its temperature falls to -190°C and its pressure to 1.4 bar.

[0030] The nitrogen, cooled in this manner in the closed circuit 18, passes through a heat exchanger 16 to absorb heat from the nitrogen compressed in an open circuit 20.

[0031] This open circuit 20 comprises an inlet line 21, into which gaseous nitrogen is fed at a pressure of 1.15 bar absolute and a temperature of +15°C. This nitrogen undergoes successive compressions by a compressor unit composed of a first stage 22, a second stage 23, a third stage 24, a fourth stage 25 and a fifth stage 26.

[0032] The nitrogen of the open circuit 20 undergoes the following cooling sequence: cooling implemented by an intake heat exchanger 27, cooling implemented by a plurality of interstage heat exchangers (28, 29, 30, 31) and further cooling implemented by a final heat exchanger 32 upstream of said heat exchanger 19 located in the final part of said open circuit 20.

[0033] Said heat exchangers 27, 28, 29, 30, 31, 32, subtract heat from the nitrogen of the open circuit 20 by transferring to it the cold present in the nitrogen passing through the line 10, itself cooled by the cold subtracted from the liquid methane in the heat exchanger 4.

[0034] After collecting heat through the respective heat exchangers 11, 12, 13, 27, 28, 29, 30, 31, 32, the nitrogen of the two lines 9 and 10 flows into a common line 33, through which the nitrogen is fed to a compressor 34 which circulates it at a pressure of about 70 bar along the paths already described and in the directions

indicated by the arrows.

[0035] As a result of this, the nitrogen enters the open circuit 20 in the gaseous state through the line 21 and leaves in the liquid state through a line 3, by optimum use of the cold deriving from the vaporization of the liquid methane.

[0036] The liquid nitrogen produced in this manner can itself be used in the usual air fractionation plants to produce liquid oxygen, nitrogen and argon, and in addition for all the usual possible uses of liquid nitrogen.

[0037] Advantageously, the process for recovering cold from liquid methane by liquid nitrogen production cycles in the aforescribed manner results in substantial energy savings.

[0038] With reference to the already stated real numerical values referring to a volume of 25,000 Normal cubic metres of nitrogen, the energy consumption using this process decreases to only 3,700 kWh, so drastically reducing the current energy requirement using the common liquefaction methods (for nitrogen liquefaction).

Claims

1. A process for recovering the cold deriving from liquid methane gasification, **characterised by** cooling with the liquid methane (1) a cryogenic fluid (5), preferably nitrogen, and then using said cryogenic fluid as coolant fluid in two compressor units (14-15-16, 22-23-24-25-26) for said nitrogen cryogenic fluid, both for the interstage coolers (11, 12, 13, 27, 28, 29, 30, 31, 32) and for the intake and final delivery coolers (27, 32), the cryogenic fluid (3) compressed by a first of said compressor units (22-23-24-25-26) being liquefied in a heat exchanger (19) by the action of another cryogenic fluid circulating in closed circuit, which is continuously compressed by a second of said compressor units (14-15-16) and then expanded through a cryogenic turbine (17) to achieve cooling to a temperature lower than the liquefaction temperature of the cryogenic fluid.
2. A process as claimed in claim 1, wherein the cryogenic fluid is nitrogen which by cooling through the cryogenic turbine (17) is brought to a temperature of -190°C so as to obtain liquefaction of the nitrogen on reaching -180°C through said heat exchanger (19), the liquid nitrogen leaving through a controlled line (3) of said open circuit.
3. A process as claimed in claim 2, wherein the nitrogen is used in an air fractionation plant for the production of liquid oxygen, nitrogen and argon or for other possible uses of liquid nitrogen.
4. An apparatus for implementing the process, **characterised in that** the cryogenic fluid (preferably ni-

trogen) circulating within a first closed circuit (33) is cooled by liquid methane via heat exchanger means (4), said cooled cryogenic fluid being used to cool within a second closed circuit (18) another separate cryogenic fluid, said second closed circuit comprising compressor means (14, 15, 16), expander means (17) and heat exchanger means (19), and to cool and liquefy in an open circuit (20) a further separate cryogenic fluid, said open circuit comprising compressor means (22-26) and heat exchanger means (32), said further cryogenic fluid circulating through said heat exchanger means (19) of said second closed circuit (18) before leaving said open circuit (20).

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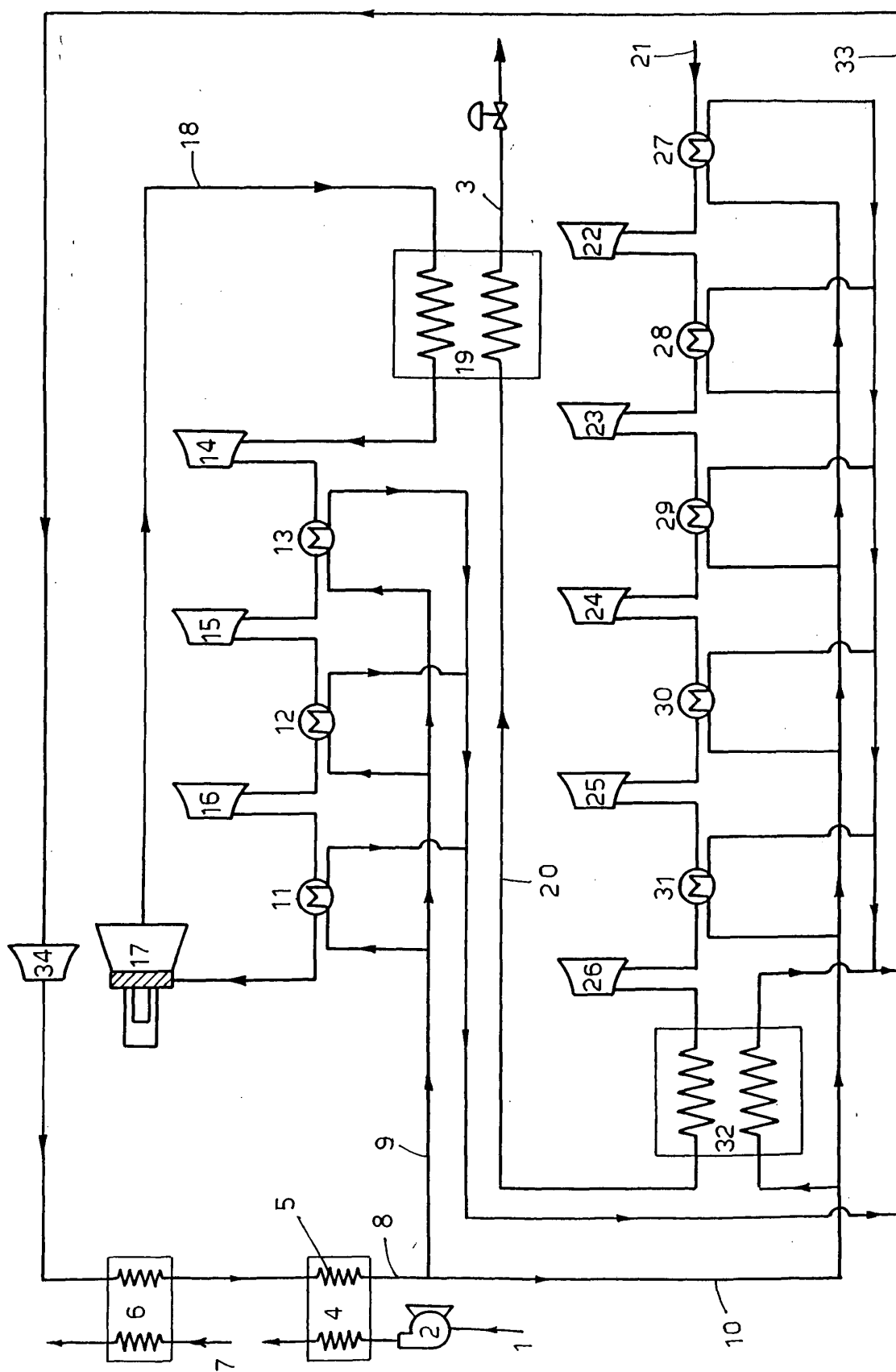
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EUROPEAN SEARCH REPORT

Application Number
EP 04 00 7031

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The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 20 July 2004	Examiner Görizt, D
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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