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

Verfahren zur Stickstoffverflüssigung durch Ausnutzung der Verdampfungskälte von flüssigem Methan

Procédé de liquéfaction d'azote en récupérant le froid obtenu par la vaporisation de méthane liquide

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(73) Proprietor: **SIAD MACCHINE IMPIANTI S.p.a.**
24126 Bergamo (IT)

(72) Inventors:
- **Bigi, Emanuele**
  24020 Gorle (Bergamo) (IT)
- **Bigi, Alessandro**
  24020 Gorle (Bergamo) (IT)

(74) Representative: **Luksch, Giorgio et al**
Giambrocono & C. s.p.a.,
Via Rosolino Pilo, 19/b
20129 Milano (IT)

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- **PATENT ABSTRACTS OF JAPAN vol. 014, no. 432 (M-1026), 17 September 1990 (1990-09-17) -& JP 02 171580 A (KOBE STEEL LTD;OTHERS: 01), 3 July 1990 (1990-07-03)**

EP 1 469 265 B1

Description

[0001] This invention relates to a process and apparatus for liquefying a cryogenic fluid comprising the features of the preamble of claims 1 and 4. Such a process, respectively apparatus, is known from JP 02 171 580 A and EP 1 055 894 A.

[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. In accordance with the present invention this object is solved by the characterizing features of claims 1 and 4.

[0020] This and other objects which will be more apparent hereinafter will be seen to have been attained on reading the ensuing description of one embodiment of the process and apparatus according to the claims.

[0021] 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.

[0022] With reference to said drawing, a liquid methane inlet line 1 leads to a pump 2. The pump 2 (indicatively 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.

[0023] 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.

[0024] 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.

[0025] 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 18, 20 of the apparatus in which said nitrogen is liquefied.

[0026] 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.

[0027] 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.

[0028] 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.

[0029] The nitrogen, cooled in this manner in the closed circuit 18, passes through a heat exchanger 19 to absorb heat from the nitrogen compressed in an open circuit 20.

[0030] 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.

[0031] 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.

[0032] 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.

[0033] 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.

[0034] 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.

[0035] 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.

[0036] Advantageously, the process for recovering cold from liquid methane by liquid nitrogen production cycles in the aforedescribed manner results in substantial energy savings.

[0037] 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 the liquefaction of a cryogenic fluid by recovering the cold derived from liquid methane gasification, comprising the steps of cooling (4) with the liquid methane (1) a first cryogenic fluid (5), preferably nitrogen, and then using said first cryogenic fluid as coolant fluid in a first compressor unit (22-23-24-25-26), both for the interstage coolers (28, 29, 30, 31) and for the intake and final delivery coolers (27, 32) of said first compressor unit, the cryogenic fluid (3) being compressed by the first compressor unit (22-23-24-25-26) and liquefied in a heat exchanger (19), by **characterized in that** the heat exchanger is cooled another separate cryogenic fluid circulating in a closed circuit, said another separate cryogenic fluid being continuously compressed by a second compressor unit (14-15-16), expanded through a cryogenic turbine (17) to achieve a cooling temperature being lower than the liquefaction temperature of the cryogenic fluid and then fed to said heat exchanger (19), and **in that** the first cryogenic fluid is also used as coolant fluid in said second compressor unit (14,15,16) both for second interstage coolers (12,13) and second final delivery cooler (11) of said second compressor unit.

2. A process as claimed in claim 1, wherein the another separate cryogenic fluid is nitrogen which by cooling through the expansion in 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 the open liquefaction 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 the liquefaction of a cryogenic fluid implementing the process, of claim 1, the apparatus comprises a first closed circuit (33) with circulating first cryogenic fluid (preferably nitrogen) and said first closed circuit comprising first heat exchanger means (4), for cooling first cryogenic fluid by liquid methane; an open circuit (20) comprising first compressor means (22-26) for compressing the cryogenic fluid and heat exchanger means (19) for liquefying the compressed cryogenic fluid (3);
the first compressor means (22-26) comprising in-

terstage coolers (28-31), intake and final delivery coolers (27,32) for cooling the cryogenic fluid wherein said coolers being cooled by said cooled first cryogenic fluid;

characterised by

a second closed circuit (18) with circulating another separate cryogenic fluid;

the second closed circuit (18) comprising second compressor means (14-16) for compressing the another separate cryogenic fluid and expander means (17) for expanding the another separate cryogenic fluid wherein the expander means (17) being connected to the heat exchanger means (19); and

the second compressor means (14-16) comprising second interstage coolers (12,13) and second final delivery cooler (11) for cooling the another separate cryogenic fluid wherein said second interstage and second final delivery coolers being cooled by said cooled first cryogenic fluid.

Patentansprüche

1. Verfahren zur Verflüssigung einer kryogenen Flüssigkeit durch die Ausnutzung der Verdampfungskälte von flüssigem Methan, welche die Schritte aufweist, Abkühlen (4) einer ersten kryogenen Flüssigkeit (5), vorzugsweise Stickstoff mit flüssigem Methan (1), und Verwendung einer ersten kryogenen Flüssigkeit als Kühlflüssigkeit in einer ersten Kompressoreinheit (22, 23, 24, 25, 26), beides für die Zwischenkühlung (28, 29, 30, 31) und für die Eingangs- und Ausgangskühler (27, 32) der ersten Kompressoreinheit, die kryogene Flüssigkeit (3) wird durch die erste Kompressoreinheit (22, 23, 24, 25, 26) komprimiert und in einem Wärmetauscher (19) verflüssigt, **dadurch gekennzeichnet, dass** der Wärmetauscher durch eine weitere separate kryogene Flüssigkeit gekühlt wird, welche in einem geschlossenen Kreislauf zirkuliert, eine weitere separate kryogene Flüssigkeit wird regelmäßig durch eine zweite Kompressoreinheit (14, 15, 16) komprimiert, und dann durch eine kryogene Turbine (17) expandiert, um eine Kühlungstemperatur zu erreichen, welche tiefer ist als die Verflüssigungstemperatur der kryogenen Flüssigkeit und welche dann in den Wärmetauscher (19) gespeist wird, in der die erste kryogene Flüssigkeit und ebenso als Kühlflüssigkeit in der zweiten Kompressoreinheit eingesetzt wird (14, 15, 16), ebenso als zweite Zwischenstufenkühlung (12, 13) und als zweite Ausgangskühlung (11) der zweiten Kompressoreinheit.

2. Verfahren nach Anspruch 1, worin die weitere separate kryogene Flüssigkeit Stickstoff ist, welche durch Abkühlung mittels der Expansion in der kryogenen Turbine (17) auf eine Temperatur von -190°C gebracht wird, so dass eine Verflüssigung des Stickstoff durch Unterschreitung der -180°C Temperatutmarke durch den Wärmetauscher (19) erreicht wird, der flüssige Stickstoff wird durch eine gesteuerte Leitung (3) des offenen Verflüssigungskreislaufs ausgestoßen.

3. Verfahren nach Anspruch 2, worin der Stickstoff in einer Lufttzerlegungsanlage zur Produktion von flüssigen Sauerstoff, Stickstoff und Argon oder für den weiteren möglichen Gebrauch von flüssigem Stickstoff aufbereitet wird.

4. Vorrichtung zur Verflüssigung einer kryogenen Flüssigkeit zur Ausführung des Verfahrens nach Anspruch 1, wobei die Vorrichtung einen ersten geschlossenen Kreislauf (33) mit einer ersten kryogenen Flüssigkeit (vorzugsweise Stickstoff) aufweist, und der erste offene Kreislauf ein erstes Wärmetauschmittel (4) zu Abkühlung einer ersten kryogenen Flüssigkeit durch flüssiges Methan aufweist; ein offener Kreislauf (20) weist erste Kompressionsmittel (22-26) zur Komprimierung der kryogenen Flüssigkeit und Wärmetauschmittel (19) zur Verflüssigung der komprimierten kryogenen Flüssigkeit (3) auf; die ersten Kompressormittel (22-26) weisen Vorstufenkühler (28 - 31) auf, Eingangs- und Ausgangskühler (27, 32) zur Kühlung der kryogenen Flüssigkeit, worin die Kühler durch die erste kryogene Flüssigkeit gekühlt werden; **gekennzeichnet durch** einen zweiten geschlossenen Kreislauf (18), in dem eine weitere separate kryogene Flüssigkeit zirkuliert; der zweite geschlossenen Kreislauf (18) weist zweite Kompressormittel (14 - 16) zur Komprimierung der weiteren separaten kryogenen Flüssigkeit und Expandermittel (17) zum Expandieren der weiteren separaten kryogenen Flüssigkeit auf, worin das Expandermittel (17) mit dem Wärmetauschermittel (19) verbunden ist; und das zweite Kompressormittel (14 -16) weist einen zweiten Zwischenstufenkühler (12, 13) auf, und einen zweiten Ausgangskühler (11) zur Kühlung der weiteren separaten kryogenen Flüssigkeit, worin die zweiten Zwischenstufen und die zweiten Ausgangskühler **durch** die erste gekühlte kryogene Flüssigkeit gekühlt werden.

Revendications

1. Procédé pour la liquéfaction d'un fluide cryogénique par récupération du froid issu de la gazéification de méthane liquide, comprenant les étapes consistant à refroidir (4) avec le méthane liquide (1) un premier fluide cryogénique (5), de préférence de l'azote, puis à utiliser ledit premier fluide cryogénique comme fluide de refroidissement dans un premier groupe compresseur (22-23-24-25-26), aussi bien pour les refroidisseurs intermédiaires (28, 29, 30, 31) que pour les refroidisseurs d'admission et de refoulement final

(27, 32) dudit premier groupe compresseur, le fluide cryogénique (3) étant comprimé par le premier groupe compresseur (22-23-24-25-26) et liquéfié dans un échangeur de chaleur (19), **caractérisé en ce que** l'échangeur de chaleur est refroidi par un autre fluide cryogénique séparé circulant en circuit fermé, ledit autre fluide cryogénique séparé étant comprimé en continu par un second groupe compresseur (14-15-16), détendu en passant dans une turbine cryogénique (17) pour obtenir une température de refroidissement inférieure à la température de liquéfaction du fluide cryogénique, puis fourni audit échangeur de chaleur (19), et **en ce que** le premier fluide cryogénique sert également de fluide de refroidissement dans ledit second groupe compresseur (14, 15, 16), à la fois pour des seconds refroidisseurs intermédiaires (12, 13) et pour un second refroidisseur de refoulement final (11) dudit second groupe compresseur.

2. Procédé selon la revendication 1, dans lequel l'autre fluide cryogénique séparé est de l'azote qui, par refroidissement du fait de la détente dans la turbine cryogénique (17), est porté à une température de -190°C de manière à obtenir une liquéfaction de l'azote en atteignant -180°C par l'intermédiaire dudit échangeur de chaleur (19), l'azote liquide sortant par une conduite commandée (3) du circuit de liquéfaction ouvert.

3. Procédé selon la revendication 2, dans lequel l'azote est employé dans une installation de séparation de l'air en vue de produire de l'oxygène, de l'azote et de l'argon liquides ou pour d'autres utilisations éventuelles d'azote liquide.

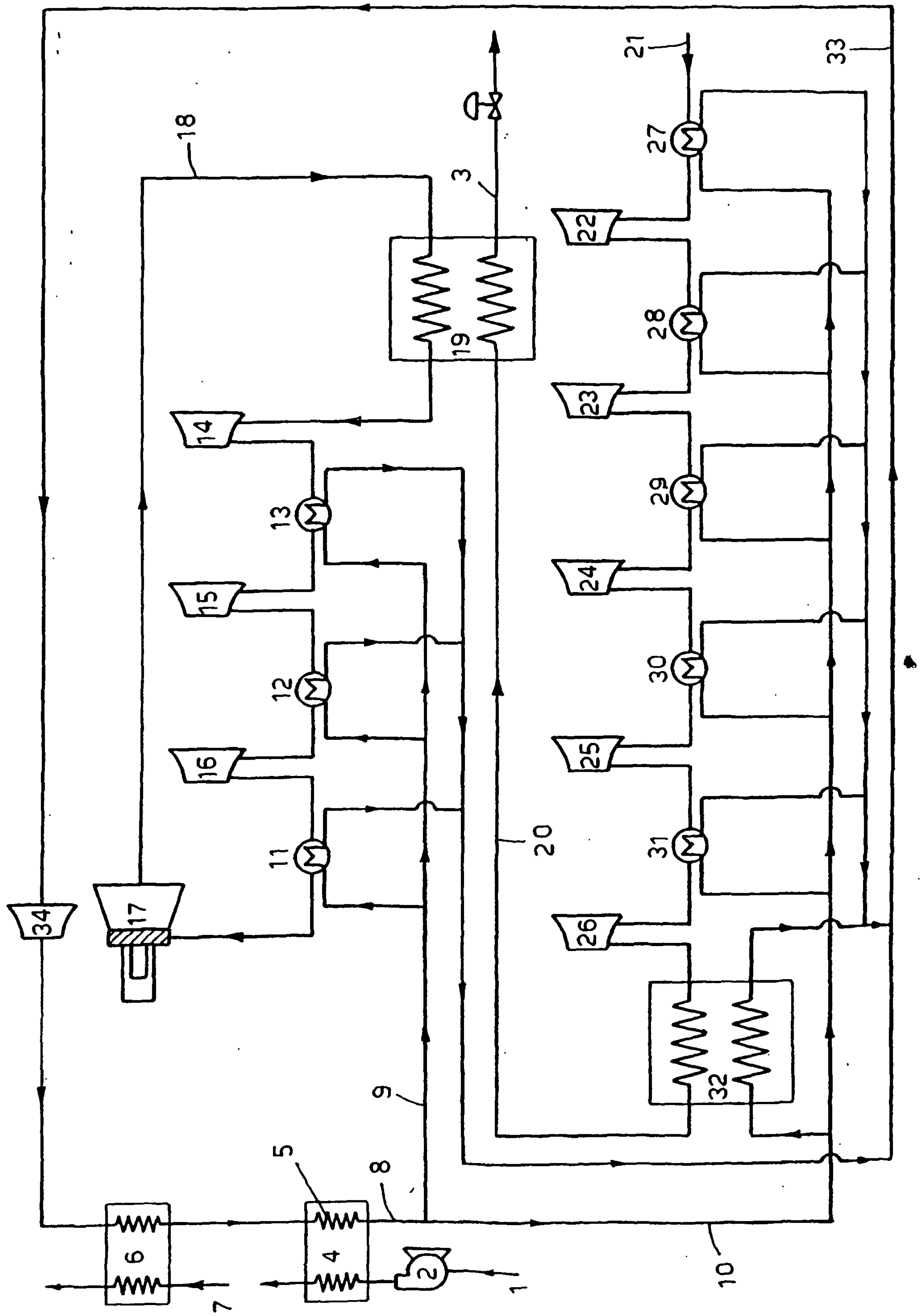
4. Dispositif pour la liquéfaction d'un fluide cryogénique mettant en oeuvre le procédé selon la revendication 1, le dispositif comprenant un premier circuit fermé (33) dans lequel circule un premier fluide cryogénique (de préférence de l'azote) et ledit premier circuit fermé comportant un premier échangeur de chaleur (4) pour refroidir le premier fluide cryogénique par du méthane liquide ;

un circuit ouvert (20) comportant des premiers moyens formant compresseur (22-26) pour comprimer le fluide cryogénique et un échangeur de chaleur (19) pour liquéfier le fluide cryogénique comprimé (3) ;

les premiers moyens formant compresseur (22-26) comportant des refroidisseurs intermédiaires (28-31), des refroidisseurs d'admission et de refoulement final (27, 32) pour refroidir le fluide cryogénique, lesdits refroidisseurs étant refroidis par ledit premier fluide cryogénique refroidi ; **caractérisé par** un second circuit fermé (18) dans lequel circule un autre fluide cryogénique séparé ;

le second circuit fermé (18) comportant des seconds moyens formant compresseur (14-16) pour comprimer l'autre fluide cryogénique séparé et un moyen formant détendeur (17) pour détendre l'autre fluide cryogénique séparé, le moyen formant détendeur (17) étant relié au moyen formant échangeur de chaleur (19) ; et

les seconds moyens formant compresseur (14-16) comportant des seconds refroidisseurs intermédiaires (12, 13) et un second refroidisseur de refoulement final (11) pour refroidir l'autre fluide cryogénique séparé, lesdits seconds refroidisseurs intermédiaires et ledit second refroidisseur de refoulement final étant refroidis par ledit premier fluide cryogénique refroidi.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