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CA 2851064 A1 2013/04/04

(21) 2 851 064

(12) **DEMANDE DE BREVET CANADIEN**
CANADIAN PATENT APPLICATION

(13) **A1**

(86) Date de dépôt PCT/PCT Filing Date: 2012/09/13
(87) Date publication PCT/PCT Publication Date: 2013/04/04
(85) Entrée phase nationale/National Entry: 2014/03/27
(86) N° demande PCT/PCT Application No.: CN 2012/081328
(87) N° publication PCT/PCT Publication No.: 2013/044732
(30) Priorité/Priority: 2011/09/30 (CN201110291607.6)

(51) Cl.Int./Int.Cl. *B01D 53/02* (2006.01), *B01D 53/26* (2006.01), *C10L 3/06* (2006.01)

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(54) Titre : PROCEDE D'ELIMINATION D'EAU ET D'ELIMINATION D'HYDROCARBURES LOURDS EN PRODUCTION DE GAZ NATUREL LIQUEFIE A PARTIR DE GAZ MELANGE RICHE EN METHANE
(54) Title: WATER REMOVAL AND HEAVY-HYDROCARBON REMOVAL PROCESS IN LIQUEFIED NATURAL GAS PRODUCTION FROM MIXED GAS RICH IN METHANE

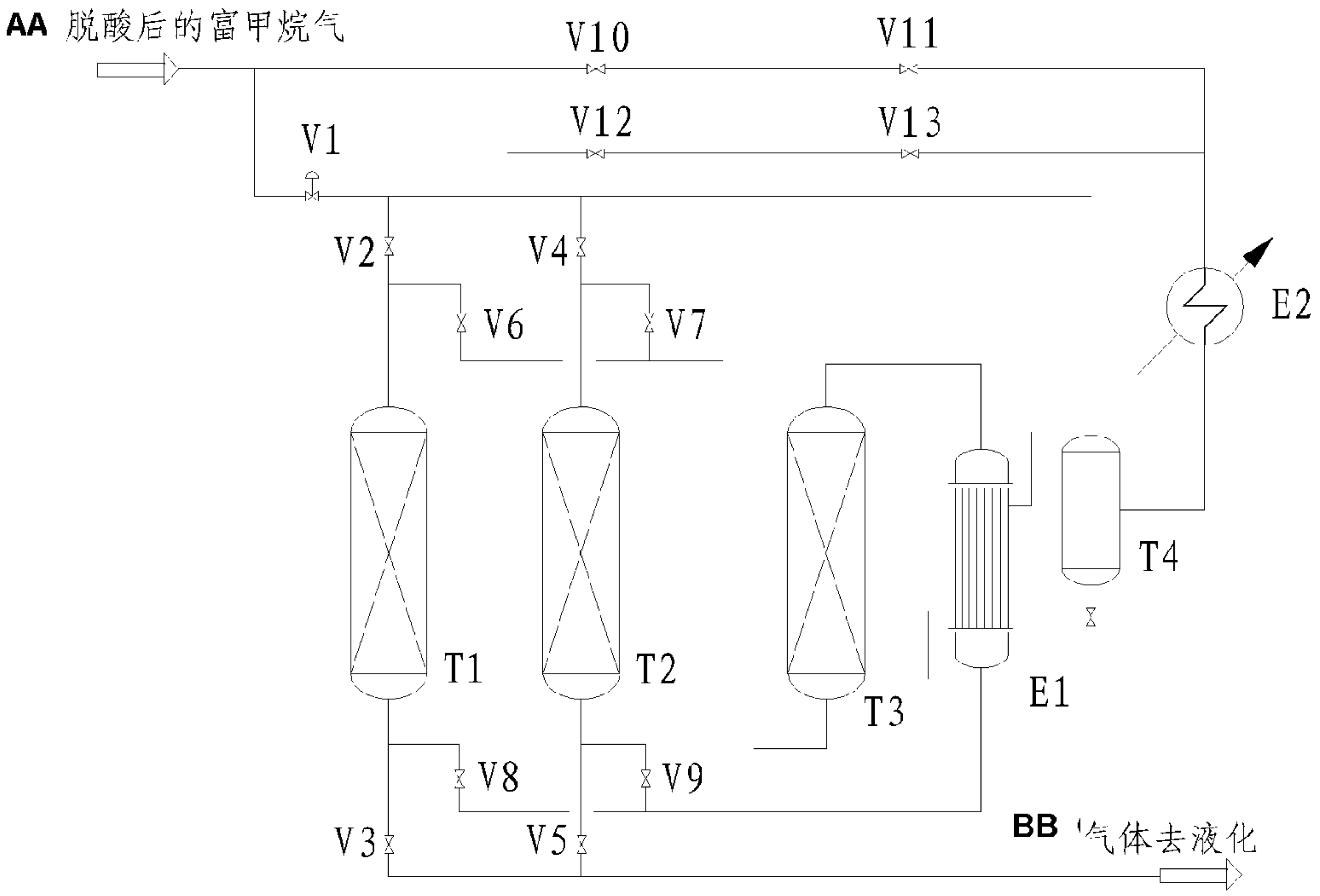

图 1 / FIG. 1

AA GAS RICH IN METHANE AFTER ACID REMOVAL
BB GAS TO BE LIQUEFIED

(57) Abrégé/Abstract:
A water removal and heavy-hydrocarbon removal process in liquefied natural gas production from a mixed gas rich in methane comprises the steps of: dividing a mixed gas rich in methane after acid removal treatment into two parts, wherein one part enters a

(57) Abrégé(suite)/Abstract(continued):
drying procedure as a process gas, and the other part enters a regeneration procedure as a regeneration gas, the mixed gas rich in methane that enters the drying procedure is subjected to drying treatment, and moisture and heavy hydrocarbons C6 or higher in the gas are removed at the same time in a composite bed of an absorbent in a drying tower, and the moisture is removed to a normal-pressure dew point of lower than or equal to -76°C, the heavy hydrocarbons C6 or higher are removed to a concentration of lower than or equal to 217 ppm; after the regeneration process of the mixed gas rich in methane that enters the regeneration procedure as a regeneration gas of the regeneration process of the drying tower is completed, returning this part of regenerated gas back into the system process gas flow. Also provided is a water removal and heavy-hydrocarbon removal unit in liquefied natural gas production from a mixed gas rich in methane. The unit comprises: a first drying tower (T1), a second drying tower (T2), a third drying tower (T3), a heater (E1), a gas-liquid separator (T4) and a cooler (E2), wherein the first drying tower (T1) and the second drying tower (T2) are in a drying procedure and a regeneration procedure alternately.

(12) 按照专利合作条约所公布的国际申请

(19) 世界知识产权组织
国 际 局

(43) 国际公布日
2013 年 4 月 4 日 (04.04.2013)

WIPO | PCT

(10) 国际公布号
WO 2013/044732 A1

(51) 国际专利分类号:
B01D 53/02 (2006.01) *C10L 3/06* (2006.01)
B01D 53/26 (2006.01)

(21) 国际申请号: PCT/CN2012/081328

(22) 国际申请日: 2012 年 9 月 13 日 (13.09.2012)

(25) 申请语言: 中文

(26) 公布语言: 中文

(30) 优先权:
201110291607.6 2011 年 9 月 30 日 (30.09.2011) CN

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(81) 指定国 (除另有指明，要求每一种可提供的国家保护): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT,

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(54) **Title**: WATER REMOVAL AND HEAVY-HYDROCARBON REMOVAL PROCESS IN LIQUEFIED NATURAL GAS PRODUCTION FROM MIXED GAS RICH IN METHANE

(54) **发明名称** : 从富含甲烷的混合气体中生产液化天然气的脱水脱重烃工艺

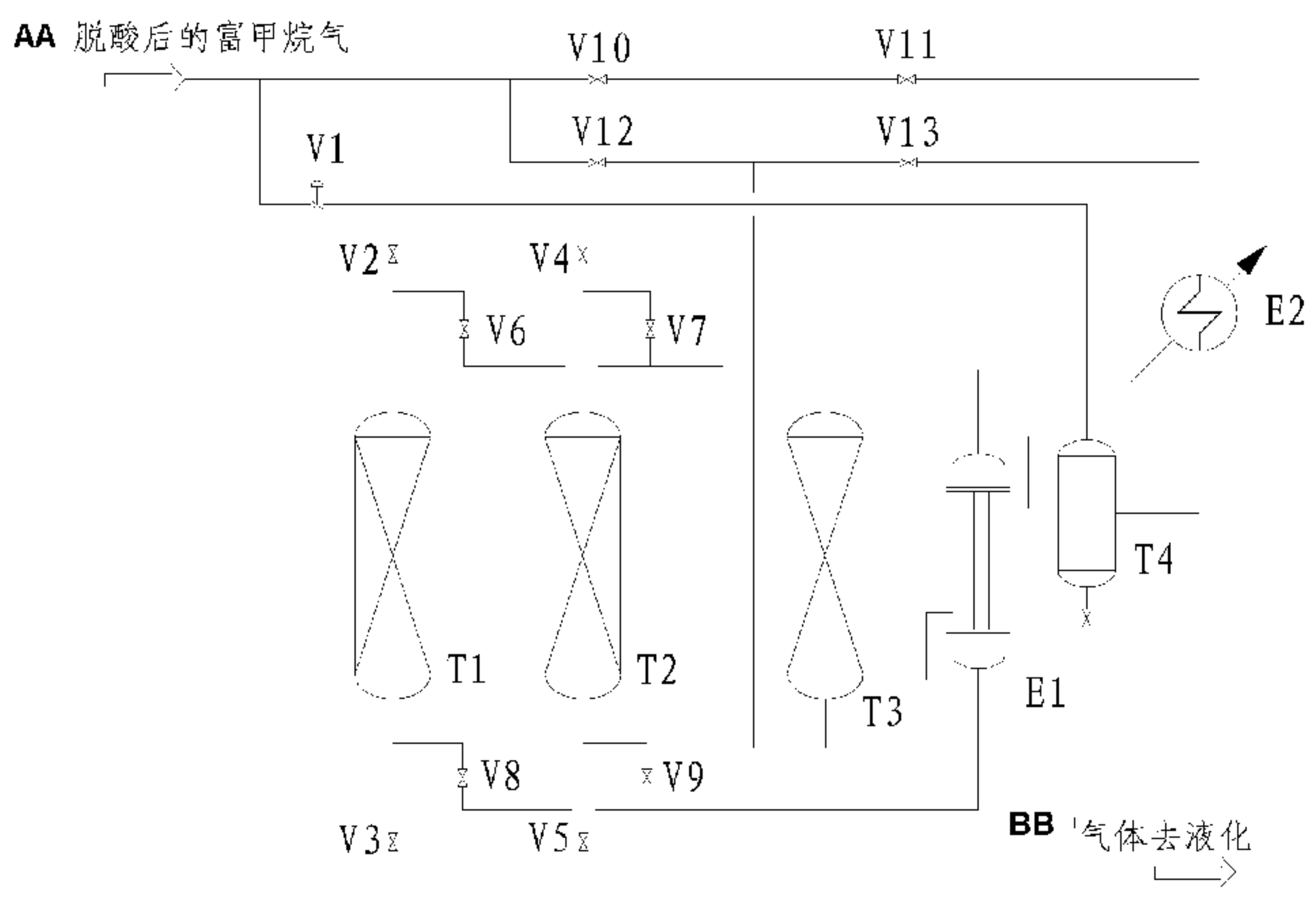

图 1 / FIG. 1

AA GAS RICH IN METHANE AFTER ACID REMOVAL
BB GAS TO BE LIQUEFIED

(57) **Abstract**: A water removal and heavy-hydrocarbon removal process in liquefied natural gas production from a mixed gas rich in methane comprises the steps of: dividing a mixed gas rich in methane after acid removal treatment into two parts, wherein one part enters a drying procedure as a process gas, and the other part enters a regeneration procedure as a regeneration gas, the mixed gas rich in methane that enters the drying procedure is subjected to drying treatment, and moisture and heavy hydrocarbons C6 or higher in the gas are removed at the same time in a composite bed of an absorbent in a drying tower, and the moisture is removed to a normal-pressure dew point of lower than or equal to -76°C, the heavy hydrocarbons C6 or higher are removed to a concentration of lower than or equal to 217 ppm; after the regeneration process of the mixed gas rich in methane that enters the regeneration procedure as a regeneration gas of the regeneration process of the drying tower is completed, returning this part of regenerated gas back into the system process gas flow. Also provided is a water removal and heavy-hydrocarbon removal unit in liquefied natural gas production from a mixed gas rich in methane. The unit comprises: a first drying tower (T1), a second drying tower (T2), a third drying tower (T3), a heater (E1), a gas-liquid separator (T4) and a cooler (E2), wherein the first drying tower (T1) and the second drying tower (T2) are in a drying procedure and a regeneration procedure alternately.

(57) **摘要**:

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WO 2013/044732 A1

WO 2013/044732 A1

QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW。

(84) **指定国** (除另有指明，要求每一种可提供的地区保护): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), 欧亚 (AM, AZ, BY, KG, KZ, RU, TJ, TM), 欧洲 (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)。

本国际公布:

— 包括国际检索报告(条约第 21 条(3))。

一种从富含甲烷的混合气体中生产液化天然气的脱水脱重烃工艺，其步骤包括：经脱酸处理后的富含甲烷混合气体分成两部分，一部分作为工艺气流进入干燥工序，另一部分作为再生气进入再生工序，进入干燥工序的富含甲烷混合气体经干燥处理，在干燥塔吸附剂复合床层中同时脱除气体中的水分和 C6 以上的重烃，水分脱除至常压露点≤-76℃，C6 以上的重烃组分脱除至≤217ppm；进入再生工序的富含甲烷混合气体作为干燥塔再生过程的再生气体，完成再生过程后，该部分再生气返回系统工艺气流中。还提供一种从富含甲烷的混合气体中生产液化天然气的脱水脱重烃装置，该装置包括：第一干燥塔（T1）和第二干燥塔（T2），第一干燥塔（T1）和第二干燥塔（T2）二者交替地处于干燥过程和再生过程，第三干燥塔（T3），加热器（E1），气液分离器（T4）和冷却器（E2）。

Specification

WATER REMOVAL AND HEAVY-HYDROCARBON REMOVAL PROCESS IN LIQUEFIED NATURAL GAS PRODUCTION FROM MIXED GAS RICH IN METHANE

Field of the Invention

The present invention relates to a front-end purifying treatment technology in the methane-rich gas cryogenic liquefaction, more specifically a process for dehydrating and removing heavy hydrocarbons in production of liquefied natural gas (LNG) from a methane-rich gas mixture and an apparatus for this process.

Background of the Invention

Due to the pressure from environment protection and energy source cost, the using proportion of the natural gas, as a kind of primary energy, in various fields of the society is gradually promoted, and the market requirement for natural gas is also rapidly increased. The traditional mode of transportation and supply by pipeline still remains a mainstream, but due to the limitation from gas-feed conditions and consumer distribution, a large part of energy resources cannot be transported by pipeline in long distance, so we have to select a liquefying mode, i.e., we transform the methane gas to a liquid and then use a flexible mode of transportation to transport the liquid to user terminals. The volume of liquefied natural gas（LNG）corresponds to 1/625 of volume of the same amount of gaseous natural gas, by liquefaction, the cost of storage and transportation can be reduced, and the combustion value of per unit of volume can also be increased.

In a industrial-scale apparatus to obtain liquefied natural gas(LNG) from a methane-rich gas mixture, before performing a cryogenic liquefaction of the gas mixture, the acidic gas components, the water and the high-carbon hydrocarbons (≥ C6) etc. contained in the gas mixture must be removed to a degree required by liquefaction, so the stable safety operation of the liquefaction separation process and the apparatus can be ensured. As to the operating conditions of several LNG apparatuses put into service in China, the front-end purifying section of gas mixture usually utilizes an acidic gas removing unit, a drying and adsorbing unit, and a heavy hydrocarbon removing unit, etc. to remove impurity components in successive steps, the drawbacks of these operating conditions consist in that the equipment investment is higher and the energy consumption of the system under normal operating mode is also higher.

Summary of the Invention

In view of above technical problems, the first aspect of the present invention is to provide a process for dehydrating (i.e., removing water) and removing heavy hydrocarbons in the production of liquefied natural gas from a methane-rich gas mixture, characterized in that:

The methane-rich gas mixture after deacidification (i.e., acidic gas removing) treatment is divided into two streams(or two parts), i.e. the first stream and the second stream, wherein the first stream used as a system process gas(or gas stream, or called as feed gas) is introduced into a drying procedure, and the second stream used as regenerating gas is introduced into a regenerating procedure,

The first stream is subjected to a drying treatment, and the moisture and heavy hydrocarbons are simultaneously removed from the first stream in a composite adsorbent bed(s) of a drying tower, wherein the moisture is removed such that the dew point at normal pressure (or atmosphere pressure) is less than or equivalent to (i.e. ≤) -76℃ and the heavy hydrocarbon components of C6 and higher (i.e., >C6 or more than 6 carbon atoms) are removed such that the content of these components is ≤ 217ppm (preferably ≤ 200ppm, more preferably ≤ 100ppm, further preferably ≤ 50ppm, and most preferably ≤ 10ppm); and the second stream (or part) of methane-rich gas mixture is used as a regenerating gas in the regenerating procedure of the above-mentioned drying tower, subjected to a regenerating process and then returned as a part of the system process gas (which will comes into the drying tower under (or at) an adsorption process).

In the present application, "procedure" and "process" have the same meaning and can be used interchangeably.

Preferably, the present invention provides a process for dehydrating and removing heavy hydrocarbons in the production of liquefied natural gas from a methane-rich gas mixture, which is characterized in that:

The methane-rich gas mixture after deacidification treatment is divided by a flow-regulating valve into two streams;

The first stream used as a feed gas (or a process gas) is introduced directly to a first drying tower or a second drying tower under (or at) a drying process, wherein the first drying tower and the second drying tower carry out the drying process and the regenerating process alternatively, a drying agent (such as 3A or 4A molecular sieves, and/or activated aluminium oxide) and a heavy hydrocarbon adsorbent (such as activated carbon and/or water-resistant silica gel) loaded in the drying tower under drying process can adsorb the moisture and the heavy hydrocarbons from the first stream, and the dew point under normal pressure of the product gas obtained after the drying process is less than or equivalent to (i.e. ≤) -76℃, and the heavy hydrocarbon components of C6 and higher are removed such that the content of these components is ≤ 217ppm (preferably ≤ 200ppm, more preferably ≤ 100ppm, further preferably ≤ 50ppm, still further preferably ≤ 30ppm, still further preferably ≤ 20ppm, most preferably ≤ 10ppm);

The second stream is used as a regenerating gas (or called as a gas for regenerating) to carry out a regenerating process in the drying tower(s), wherein the regenerating process in the drying tower(s) include a heating regenerating step and a cold-blowing step;

In the heating-regenerating step, the second stream is dried firstly by the third drying tower and heated by a heater to e.g. 200-300℃ (preferably 210-280℃, more preferably 220-260℃, still preferably 240℃ more or less), and the heated stream is sent to the drying tower which needs regenerating to heat the latter (when the first drying tower is under (or at) drying process, the second drying tower is under regenerating process, vice versa), so the adsorbents loaded in this drying tower is heated up, the moisture and the heavy hydrocarbons are desorbed (or stripped) from the adsorbents, and then, the gas stream that has experienced desorption is cooled and subjected to a liquid-separating operation to obtain a treated gas stream, and the treated stream is converged with the first stream used as the feed gas so as to obtain a mixed gas stream, and the mixed stream is sent to the drying tower under drying process to carry out drying;

In the cold-blowing step, a regenerating gas taken from the methane-rich gas mixture after deacidification treatment is sent directly to the second drying tower or the first drying tower under regenerating process, such that the temperature of the drying tower is lowered by the regenerating gas to normal temperature; the regenerating gas is heated by a heater and then sent to the above-mentioned third drying tower, so as to heat and dry the adsorbents in the third drying tower; and the regenerating gas is cooled and subjected to a liquid-separating operation to obtain a treated gas stream, and the treated stream is mixed with the first stream used as the feed gas so as to obtain a mixed gas stream, and finally the mixed stream is sent to the first drying tower or the second drying tower under drying process to carry out drying.

In general, 3A molecular sieve, 4A molecular sieve or activated aluminium oxide can be used as a dehydration adsorbent, while activated carbon or water-resistant silica gel can be used as an adsorbent for removing heavy hydrocarbons.

The another aspect of the present invention is to provide an apparatus for dehydrating and removing heavy hydrocarbons in the production of liquefied natural gas from a methane-rich gas mixture, said apparatus includes:

The first drying tower and the second drying tower, wherein the first drying tower and the second drying tower are under the drying process and the regenerating process alternately or perform the said two process alternately,

A third drying tower (i.e., a supplemental drying tower),

A heater,

A gas-liquid separator, and

A Cooler,

Every drying tower has one or more composite adsorbent bed(s), for example 3-20 beds, 4-18 beds, 5-16 beds, 6-14 beds or 8-12 beds.

A pipe for supply of the methane-rich gas mixture after deacidification (i.e. the feed gas or the process gas) is divided into two sub-pipes, i.e., a first sub-pipe and a second sub-pipe, the first valve (i.e., flow-regulating valve) is provided in the first sub-pipe; and in the downstream of the first valve, the first sub-pipe is subdivided into three branch pipes, wherein the first branch pipe is connected in order via(or by way of) the second valve, an inlet pipe of the first drying tower (refers to the inlet pipe of the first drying tower when the first drying tower is under drying process), the first drying tower and the third valve to a liquefaction system, the second branch pipe is connected in order via the fourth valve, an inlet pipe of the second drying tower, the second drying tower and the fifth valve to the liquefaction system, and the third branch pipe is connected in order via an optional valve (not shown), an outlet pipe of a gas-liquid separator, the gas-liquid separator, and an inlet pipe of the gas-liquid separator to an outlet port of a cooler;

The above-mentioned second sub-pipe is connected via a tenth valve and an eleventh valve and additionally via a twelfth valve and a thirteenth valve to a inlet pipe of the cooler; a first side tube is branched between the first drying tower and the third valve and also a second side tube is branched between the second drying tower and the fifth valve, the two side tubes are joined together after passed respectively through an eighth valve and a ninth valve and then connected to one end (upper end or lower end) of the heater, and another end of the heater is connected to one end (upper end or lower end) of the third drying tower, while another end of the third drying tower is connected via a pipe to a conduit between the twelfth valve and the thirteenth valve; a third side tube is branched between the first drying tower and the second valve and also a fourth side tube is branched between the second drying tower and the fourth valve, the two side tubes are joined together after passed respectively through a sixth valve and a seventh valve and then connect to a conduit between the tenth valve and the eleventh valve.

Every process may be controlled by means of these valves.

Each adsorbent composite bed of every drying tower may loads, respectively, one or two or more of adsorbents selected from 3A or 4A molecular sieve, activated aluminium oxide, activated carbon and water-resistant silica gel, wherein the 3A molecular sieve, the 4A molecular sieve or the activated aluminium oxide is used as a dehydrating adsorbent, and the activated carbon or the water-resistant silica gel is used as a heavy hydrocarbon removing adsorbent.

Preferably, every drying tower has at least two composite adsorbent beds which are loaded respectively with a dehydrating adsorbent and a heavy hydrocarbon removing adsorbent, more preferably has three, four, five, six, seven, eight, nine, ten, eleven, twelve, thirteen, fourteen, fifteen or sixteen composite adsorbent beds.

The present invention process for drying/dehydrating and removing heavy hydrocarbons in combination in the production of liquefied natural gas from a methane-rich gas mixture is more simple than the conventional process, and can achieve good purifying effects and reduce energy consumption in the purification process. Furthermore, the operation target of each unit becomes more clear and easy to control.

The process for drying/dehydrating and removing heavy hydrocarbons in combination in the production of liquefied natural gas from a methane-rich gas mixture of the present invention utilizes composite bed(s) to remove the moisture and the heavy hydrocarbons simultaneously; the methane-rich gas mixture after deacidification treatment is subjected continually to the three-tower isobaric drying treatment, and these treatments utilize composite adsorbent bed(s) to remove simultaneously the moisture and the heavy hydrocarbons from the gas mixture stream, wherein the moisture is removed such that the dew point at normal pressure (or atmosphere pressure) is ≤ -76℃ and the heavy hydrocarbon components of C6 and higher (i.e., >C6) are removed such that the content of these components is ≤ 217ppm (preferably ≤ 200ppm, more preferably ≤ 100ppm, further preferably ≤ 50ppm, still further preferably ≤ 30ppm, still further preferably ≤ 20ppm, and most preferably ≤ 10ppm). A part of methane-rich gas mixture as a regenerating gas is used to carry out regeneration, and then this part of regenerating gas which has finished regenerating process returns to the system process gas.

Advantages of present invention:

1. By utilizing composite bed(s) to simultaneously remove the moisture and the heavy hydrocarbons, the equipment investment and also late-stage energy consumption of the system can be reduced.

2. As a process of isobaric drying/dehydrating and heavy hydrocarbon removing is used, the absorption, heating and cooling processes of the drying tower can be operated at nearly the same pressure, which increases the service life of the program-controlled valve.

3. Need not to use a purified gas as the regenerating gas and the latter can be taken from the process gas, so the flow scheme of the process become simple, and also the start or stop of the system become convenient in view of the fact that it is a independent system.

4. As we utilize a three-tower flow scheme, and when we carry the cold blowing operation, the heat stored in the heated drying tower is transferred to the next tower, so the energy consumption of the system is low.

Brief Description of the Drawing

Figure 1 is the apparatus for the process of dehydrating and heavy hydrocarbon removing in combination.

The mode of carrying out the Invention

The present invention provides a process for drying/dehydrating and heavy hydrocarbon removing in combination in the production of liquefied natural gas from a methane-rich gas mixture, wherein the process utilizes the composite adsorbent bed(s) to remove the moisture and the heavy hydrocarbons simultaneously; the methane-rich gas mixture after deacidification treatment is subjected continually to the three-tower isobaric drying treatment, and these treatments utilize composite adsorbent bed(s) to remove simultaneously the moisture and heavy hydrocarbons from the gas mixture stream, wherein the moisture is removed such that the dew point at normal pressure (or atmosphere pressure) is $\leqslant$ -76℃ and the heavy hydrocarbon components of C6 and higher (i.e., >C6) are removed such that the content of these components is $\leqslant$ 217ppm (preferably $\leqslant$ 200ppm, more preferably $\leqslant$ 100ppm, further preferably $\leqslant$ 50ppm, and most preferably $\leqslant$ 10ppm). Further, a part of methane-rich gas mixture as a regenerating gas is used to carry out regeneration, and then this part of regenerating gas which has finished regenerating process returns to the system process gas.

Referring to Figure 1, an apparatus for dehydrating and removing heavy hydrocarbons in the production of liquefied natural gas from a methane-rich gas mixture of the present invention include:

A first drying tower (T1) and a second drying tower (T2), wherein the first drying tower and the second drying tower are under the drying process and the regenerating process alternately or perform the said two process alternately,

A third drying tower (T3) (i.e., a supplemental drying tower),

A heater (E1),

A gas-liquid separator (T4), and

A cooler (E2),

Every drying tower has one or more composite adsorbent bed(s), for example 3-20 beds, 4-18 beds, 5-16 beds, 6-14 beds or 8-12 beds,

A pipe for supply of the methane-rich gas mixture after deacidification (i.e. the feed gas or the process gas) is divided into two sub-pipes, i.e., a first sub-pipe and a second sub-pipe, the first valve V1(i.e., flow-regulating valve) is provided in the first sub-pipe; and in the downstream of the first valve V1, the first sub-pipe is subdivided into three branch pipes, wherein the first branch pipe is connected in order via (or by way of) the second valve V2, an inlet pipe of the first drying tower T1(refers to the inlet pipe of the first drying tower when the first drying tower is under drying process), the first drying tower T1 and the third valve V3 to a liquefaction system, the second branch pipe is connected in order via the fourth valve V4, an inlet pipe of the second drying tower T2, the second drying tower T2 and the fifth valve V5 to the liquefaction system, and the third branch pipe is connected in order via an optional valve (not shown), an outlet pipe of a gas-liquid separator T4, the gas-liquid separator T4, and an inlet pipe of the gas-liquid separator T4 to an outlet port of the cooler E2;

The above-mentioned second sub-pipe is connected via a tenth valve V10 and an eleventh valve V11 and additionally via a twelfth valve V12 and a thirteenth valve V13 to an inlet pipe of the cooler E2; a first side tube is branched between the first drying tower T1 and the third valve V3 and also a second side tube is branched between the second drying tower T2 and the fifth valve V5, the two side tubes are joined together after passed respectively through an eighth valve V8 and a ninth valve V9, and then connected to one end (upper end or lower end) of the heater E1, and another end of the heater E1 is connected to one end (upper end or lower end) of the third drying tower T3, while another end of the third drying tower T3 is connected via a pipe to a conduit between the twelfth valve V12 and the thirteenth valve V13; a third side tube is branched between the first drying tower T1 and the second valve V2 and also a fourth side tube is branched between the second drying tower T2 and the fourth valve V4, the two side tubes are joined together after passed respectively through an sixth valve V6 and a seventh valve V7, and then connected to a conduit between the tenth valve V10 and the eleventh valve V11.

Now referring to figure 1, we illustrate the process of drying/dehydrating and removing heavy hydrocarbons in combination:

The apparatus for drying/dehydrating and removing heavy hydrocarbons in combination comprises three drying towers T1, T2 and T3, a heater E1, a cooler E2, a gas-liquid separator T4; among the three drying towers, there are two main drying towers T1 and T2 and one supplemental drying tower T3; the two main drying towers carry out drying and regenerating operation alternately; the regenerating operation include a heating step and a cooling step; the dew point at normal pressure of the obtained product gas which has subjected to drying and heavy hydrocarbons removing operation is less than or equivalent to (i.e., ≤) -76℃, whereas the heavy hydrocarbon components of C6 and higher are removed to a content of ≤ 217ppm (preferably ≤ 200ppm, preferably ≤ 100ppm, further preferably ≤ 50ppm, most preferably ≤ 10ppm).

In the isobaric process for drying/dehydrating and removing heavy hydrocarbons in combination of the present invention, the regenerating gas is taken from the process gas and, after subjected to regenerating process, is returned to the process gas stream. In comparison to those traditional processes, the process of the present invention can lower the wasting of process gas, and can increase the ratio of liquefaction of the gas stream. As the unit of drying/dehydrating and removing heavy hydrocarbon utilizes composite adsorbent bed(s), it can simultaneously remove the moisture and the heavy hydrocarbons, and can lower the equipment investment and the late-stage system energy consumption. Furthermore, the adsorbing, heating and cooling processes of the drying tower can operate under almost the same pressure, which increases the service life of the equipment.

Now take the adsorption in the drying tower T1 as an example, to illustrate its operating process:

The methane-rich gas mixture after removing acidic gases is firstly divided into two sub-streams, the flow rates of the two sub-stream is regulated by the flow-regulating valve V1: one sub-stream is used as regenerating gas, and another sub-stream is used as mainstream gas (i.e., process gas). The mainstream gas is introduced directly to the drying tower T1 via the valve V2, and the drying agent(s) and the heavy hydrocarbons removing agent(s) loaded in the drying tower T1 can adsorb the moisture and the heavy hydrocarbons contained in the gas stream so as to obtain a purified gas, and then the purified gas is introduced to the successive liquefaction procedure via the valve V3.

Meanwhile another drying tower T2 is under regenerating process, and the regenerating process of the drying tower T2 comprises a heating step and a cold-blowing step:

In the heating/regenerating step, the regenerating gas is passed through the valve V12, the drying tower T3, the heater E1, the valve V9, the drying tower T2, the valve V7, the valve V11, the cooler E2, and the gas-liquid separator T4, and then joined together with the process gas which will enter into the drying tower T1 under (or being subjected to) adsorption process, so as to obtain a joined gas stream. Thereafter, the latter is entered via the valve V2 into the drying tower T1 under adsorption process, in order to achieve the heating process of the drying tower T2.

The regenerating gas is taken from the process gas, the heating/regenerating process needs not any carrier gas of external source, and after the regenerating gas has been subjected to the regenerating step, it will returns to the process gas. The regenerating gas may heat the drying tower T2, at the same time, it may cool the tower T3 for predrying so as to carry the heat accumulated in the adsorbents and other materials in the drying tower T3 away and then enter into the heater E1, thereby the energy consumption for the heating-regenerating can be reduced. The regenerating gas has been subjected to a predrying in the drying tower T3 before it enters into the drying tower T2, therefore the moisture content in the regenerating gas is much lower (the moisture content in the feed gas usually is reduced by 80-99%), such that the drying load of the drying tower T2 can be lowered.

In the cold-blowing step, the regenerating gas is passed through the valve V10, the valve V7, the drying tower T2, the valve V9, the heater E1, the drying tower T3, the valve V13, the cooler E2, and the gas-liquid separator T4 in sequence and then joined together with the process gas which will enter into the drying tower T1 under (or being subjected to) adsorption process, so as to obtain a joined gas stream. The latter is introduced via the valve V2 into the drying tower T1 under adsorption process, in order to achieve the cooling process of the drying tower T2.

In the same way, the regenerating gas is taken from the process gas, the heating-regenerating process needs not any carrier gas of external source, and after the regenerating gas has been subjected to the regenerating step, it will returns to the process gas. The regenerating gas may cool the drying tower T2, at the same time, it may heat the tower T3 for predrying, so as to carry the heat accumulated in the adsorbents and other materials in the drying tower T2 away and then enter into the heater E1, thereby the energy consumption for the heating-regenerating can be reduced. The regenerating gas has been subjected to a predrying in the drying tower T2 before it enters into the drying tower T3, therefore the moisture content in the regenerating gas is much lower, such that the drying load of the drying tower T3 can be lowered.

After the drying tower T2 has been subjected to the above-mentioned heating process and the cooling process, it will wait for the next adsorption operation.

The regenerating process in the drying tower T1 is nearly all the same to that in the drying tower T2, except that the serial numbers of valves to be operated are different. The two drying towers carry out the adsorption and the regeneration alternately, so as to treat the gas mixture by a continuous operation.

The composite bed(s) of each drying tower may load one or more of adsorbents selected from 3A or 4A molecular sieve, activated aluminium oxide, activated carbon and silica gel.

Subsequently, take the adsorption in the drying tower T2 as an example, to illustrate its operating process:

The methane-rich gas mixture after removing acidic gases is firstly divided into two sub-streams, the flow rates of the two sub-stream is regulated by flow-regulating valve V1: one sub-stream is used as regenerating gas, and another sub-stream is used as mainstream gas (i.e., process gas). The mainstream gas is introduced directly via the valve V4 to the drying tower T2, and the drying agent(s) and the heavy hydrocarbons removing agent(s) loaded in the drying tower T2 can adsorb the moisture and the heavy hydrocarbons contained in the gas stream so as to obtain a purified gas, and then the purified gas is introduced to the successive liquefaction procedure via the valve V5.

Meanwhile another drying tower T1 is under regenerating process, and the regenerating process of the drying tower T1 comprises a heating step and a cold-blowing step:

In the heating regenerating step, the regenerating gas is passed through via the valve V12, the drying tower T3, the heater E1, the valve V8, the drying tower T1, the valve V6, the valve V11, the cooler E2, and the gas-liquid separator T4 in sequence and then joined together with the process gas which will enter into the drying tower T2 under (or being subjected to) adsorption process, so as to obtain a joined gas stream. Thereafter, the latter is entered via the valve V4 into the drying tower T2 under adsorption process, in order to achieve the heating process of the drying tower T1.

The regenerating gas is taken from the process gas, the heating/regenerating process needs not any carrier gas of external source, and after the regenerating gas has been subjected to the regenerating step, it will returns to the process gas. The regenerating gas may heat the drying tower T1, at the same time, it may cool the tower T3 for predrying so as to carry the heat accumulated in the adsorbents and other materials in the drying tower T3 away and then enter into the heater E1, thereby the energy consumption for the heating-regenerating can be reduced. The regenerating gas has been subjected to a predrying in the drying tower T3 before it enters into the drying tower T1, therefore the moisture content in the regenerating gas is much lower, such that the drying load of the drying tower T1 can be lowered.

In the cold-blowing step, the regenerating gas is passed through the valve V10, the valve V6, the drying tower T1, the valve V8, the heater E1, the drying tower T3, the valve V13, the cooler E2, and the gas-liquid separator T4 in sequence and then joined together with the process gas which will enter into the drying tower T2 under (or being subjected to) adsorption process, so as to obtain a joined gas stream. The latter is introduced via the valve V4 into the drying tower T2 under adsorption process, in order to achieve the cooling process of the drying tower T1.

In the same way, the regenerating gas is taken from the process gas, the heating-regenerating process needs not any carrier gas of external source, and after the regenerating gas has been subjected to the regenerating step, it will returns to the process gas. The regenerating gas may cool the drying tower T1, at the same time, itmay heat the tower T3 for predrying so as to carry the heat accumulated in the adsorbents and other materials in the drying tower T1 away and then enter into the heater E1, thereby the energy consumption for the heating-regenerating can be reduced. The regenerating gas has been subjected to a predrying in the drying tower T1 before it enters into the drying tower T3, therefore the moisture content in the regenerating gas is much lower, such that the drying load of the drying tower T3 can be lowered.

After the drying tower T1 has been subjected to the above-mentioned heating process and the cooling process, it will wait for the next adsorption operation.

Each composite bed of every drying tower may load, respectively, one or more of adsorbents selected from 3A or 4A molecular sieve, activated aluminium oxide, activated carbon and water-resistant silica gel. Preferably, every drying tower has at least two composite adsorbent beds which are loaded respectively with a dehydrating adsorbent and a heavy hydrocarbon removing adsorbent, more preferably three, four, five, six, seven, eight, nine, ten, eleven, twelve, thirteen, fourteen, fifteen or sixteen composite adsorbent beds.

Claims

1. A process for dehydrating and removing heavy hydrocarbons in the production of liquefied natural gas from a methane-rich gas mixture, characterized in that:
the methane-rich gas mixture subjected to deacidification treatment is divided into two streams, i.e. the first stream and the second stream, wherein the first stream used as a system process gas is introduced into a drying procedure, and the second stream used as regenerating gas is introduced into a regenerating procedure;
the first stream is subjected to a drying treatment, and the moisture and the heavy hydrocarbons are simultaneously removed from the first stream in a composite adsorbent bed(s) of a drying tower, wherein the moisture is removed such that the dew point at normal pressure is ≤ -76℃ and the heavy hydrocarbon components of C6 and higher are removed such that the content of these components is ≤ 217ppm; and
the second stream is used as a regenerating gas in the regenerating procedure of the above-mentioned drying tower, subjected to a regenerating process, and then returned as a part of the system process gas.

2. The process according to claim 1, characterized in that:

The methane-rich gas mixture after deacidification treatment is divided by a flow-regulating valve (V1) into two streams;

The first stream used as a process gas is introduced directly to a first drying tower (T1) or a second drying tower (T2) under a drying process, wherein the first drying tower (T1) and the second drying tower (T2) carry out the drying process and the regenerating process alternatively, a drying agent and a heavy hydrocarbon adsorbent loaded in the drying tower under drying process can adsorb the moisture and the heavy hydrocarbons from the first stream, and the dew point under normal pressure of the product gas obtained after the drying process is less than or equivalent to -76℃, and the heavy hydrocarbon components of C6 and higher are removed such that the content of these components is ≤ 217ppm;

The second stream is used as a regenerating gas to carry out a regenerating process in the drying tower(s), wherein the regenerating process in the drying tower include a heating-regenerating step and a cold-blowing step;

In the heating-regenerating step, the second stream is dried firstly by the third drying tower (T3) and heated by a heater (E1) to 200-300℃, and the heated stream is sent to the drying tower (T2 or T1) which needs regenerating to heat the drying tower, so the adsorbents loaded in this drying tower is heated up, the moisture and the heavy hydrocarbons are desorbed or stripped from the adsorbents, and then, the gas stream that has experienced desorption is cooled (e.g. in E2) and subjected to a liquid-separating operation (e.g. in T4) to obtain a treated gas stream, and the treated stream is converged with the first stream used as the feed gas so as to obtain a mixed gas stream, and the mixed stream is sent to the drying tower under drying process to carry out drying;

In the cold-blowing step, a regenerating gas taken from the methane-rich gas mixture after deacidification treatment is sent directly to the second drying tower (T2) or the first drying tower (T1) under regenerating process, such that the temperature of the drying tower is lowered by the regenerating gas to normal temperature; the regenerating gas is heated by a heater (E1) and then sent to the above-mentioned third drying tower (T3), so as to heat and dry the adsorbents in the third drying tower (T3); and the regenerating gas is cooled (e.g. in E2) and subjected to a liquid-separating operation (e.g. in T4) to obtain a treated gas stream, and the treated stream is mixed with the first stream used as the process gas so as to obtain a mixed gas stream, and finally the mixed stream is sent to the first drying tower or the second drying tower under drying process to carry out drying.

3. The process according to claim 1, characterized in that: each adsorbent composite bed of every drying tower may load, respectively, one or more of adsorbents selected from 3A or 4A molecular sieve, activated aluminium oxide, activated carbon and water-resistant silica gel, wherein the 3A molecular sieve, the 4A molecular sieve or the activated aluminium oxide is used as a dehydrating adsorbent, and the activated carbon or the water-resistant silica gel is used as a heavy hydrocarbon removing adsorbent.

4. An apparatus for dehydrating and removing heavy hydrocarbons in the production of a liquefied natural gas from a methane-rich gas mixture, which includes:

A first drying tower (T1) and a second drying tower (T2), wherein the first drying tower and the second drying tower are under the drying process and the regenerating process alternately or perform the said two process alternately,

A third drying tower (T3),

A heater (E1),

A gas-liquid separator (T4), and

A cooler (E2),

Each drying tower has one or more of composite adsorbent bed(s),

A pipe for supply of the methane-rich gas mixture after deacidification is divided into two sub-pipes, i.e., a first sub-pipe and a second sub-pipe, the first valve (V1) is provided in the first sub-pipe; and in the downstream of the first valve (V1), the first sub-pipe is subdivided into three branch pipes, wherein the first branch pipe is connected in order via the second valve (V2), an inlet pipe of the first drying tower (T1), first drying tower (T1) and the third valve (V3) to a liquefaction system, the second branch pipe is connected in order via the fourth valve (V4), an inlet pipe of the second drying tower (T2), the second drying tower (T2) and the fifth valve (V5) to the liquefaction system, and the third branch pipe is connected in order via an optional valve, an outlet pipe of a gas-liquid separator (T4), the gas-liquid separator (T4), and an inlet pipe of the gas-liquid separator (T4) to an outlet port of a cooler (E2);

the above-mentioned second sub-pipe is connected via a tenth valve (V10) and an eleventh valve (V11) and additionally via a twelfth valve (V12) and a thirteenth valve (V13) to an inlet pipe of the cooler (E2);

a first side tube is branched between the first drying tower (T1) and the third valve (V3) and also a second side tube is branched between the second drying tower (T2) and the fifth valve (V5), the two side tubes are joined together after passed respectively through an eighth valve (V8) and a ninth valve (V9), and then connected to one end of the heater (E1), and another end of the heater (E1) is connected to one end of the third drying tower (T3), while another end of the third drying tower (T3) is connected via a pipe to a conduit between the twelfth valve (V12) and the thirteenth valve (V13); a third side tube is branched between the first drying tower (T1) and the second valve (V2) and also a fourth side tube is branched between the second drying tower (T2) and the fourth valve (V4), the two side tubes are joined together after passed respectively through a sixth valve (V6) and a seventh valve (V7), and then connect to a conduit between the tenth valve (V10) and the eleventh valve (V11).

5. The apparatus according to claim 4, characterized in that: each adsorbent composite bed of every drying tower may load, respectively, one or more of adsorbents selected from 3A or 4A molecular sieve, activated aluminium oxide, activated carbon and water-resistant silica gel, wherein the 3A molecular sieve, the 4A molecular sieve or activated aluminium oxide is used as a dehydrating adsorbent, and

the activated carbon or the water-resistant silica gel is used as a heavy hydrocarbon removing adsorbent.

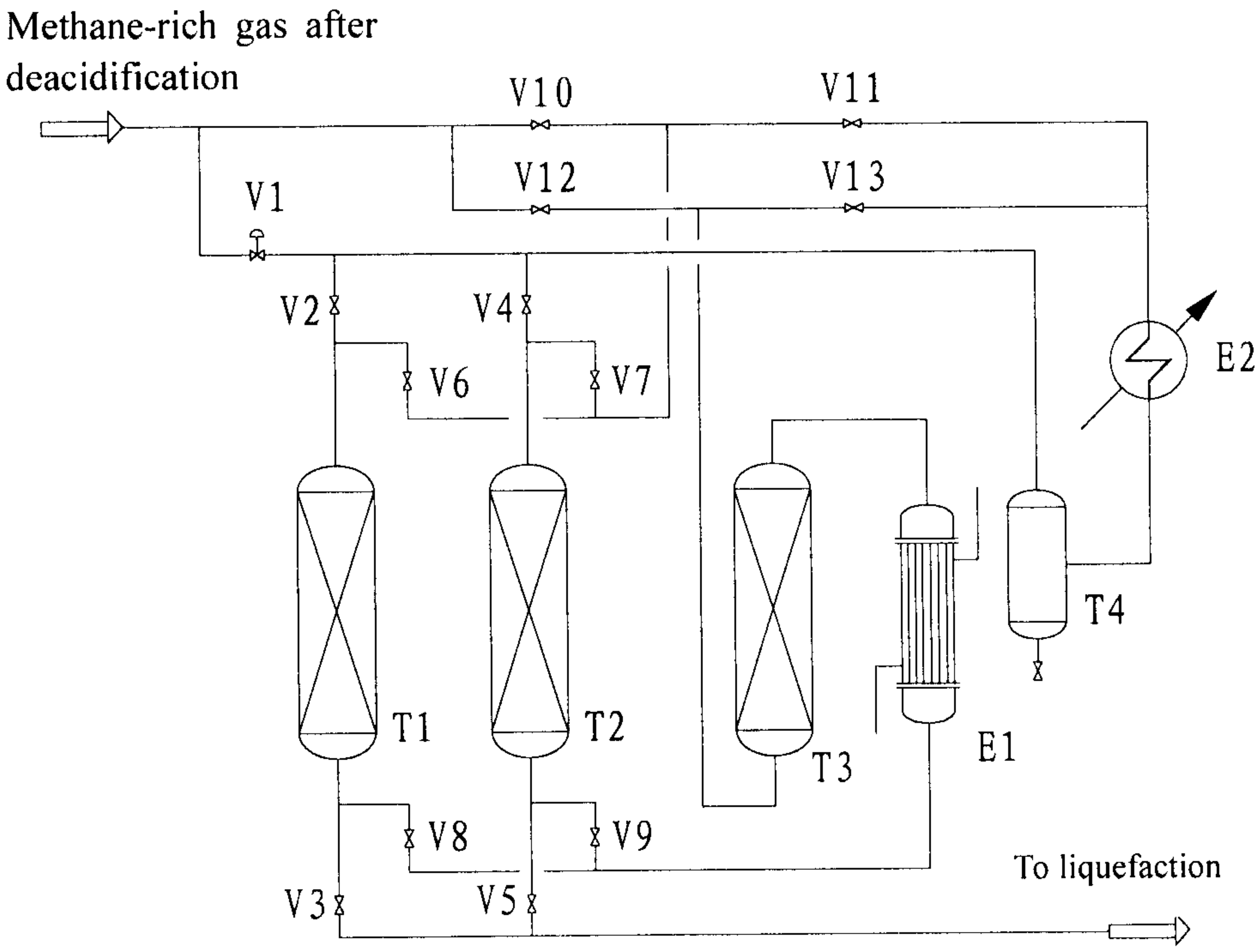
Methane-rich gas after deacidification
V10
V11
V12
V13
V1
V2
V4
V6
V7
E2
T4
T1
T2
T3
E1
V8
V9
V3
V5
To liquefaction

Figure 1

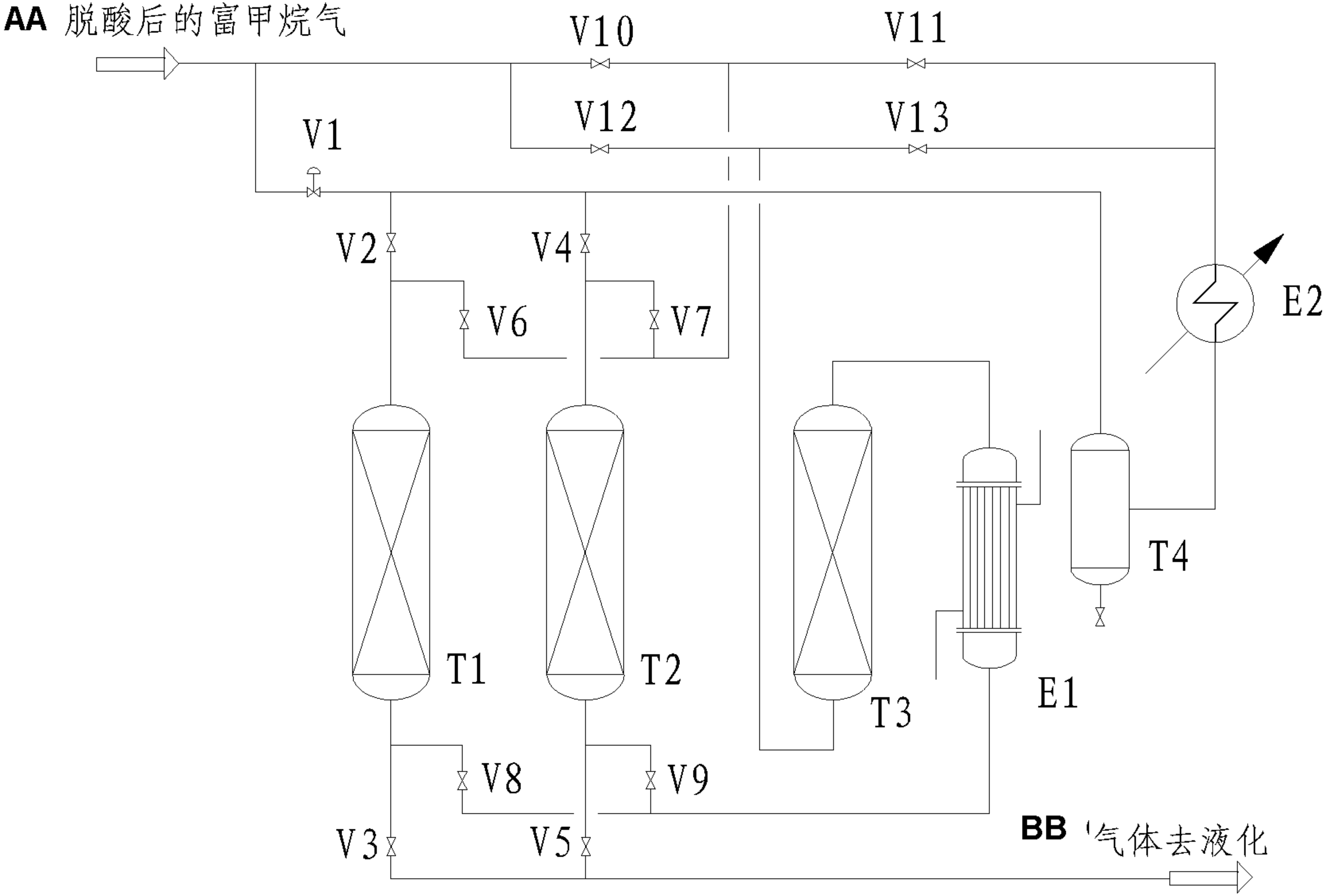

图 1 / FIG. 1

AA GAS RICH IN METHANE AFTER ACID REMOVAL
BB GAS TO BE LIQUEFIED