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(54) **NATURAL GAS LIQUEFACTION PROCESS**

ERDGASVERFLÜSSIGUNGSVERFAHREN

PROCÉDÉ DE LIQUÉFACTION DE GAZ NATUREL

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(56) References cited:

WO-A2-2012/023752	US-A- 4 901 533
US-A- 4 901 533	US-A- 5 657 643
US-A1- 2002 170 312	US-A1- 2005 056 051
US-A1- 2010 122 551	US-A1- 2010 186 445
US-A1- 2013 008 204	US-B1- 6 308 531

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Description

TECHNICAL FIELD

[0001] The present invention relates to a natural gas liquefaction process, and more particularly, to a natural gas liquefaction process which is capable of being simplified in structure and being easily operated as well as having excellent efficiency.

BACKGROUND ART

[0002] A thermodynamic process of liquefying natural gas to produce liquefied natural gas (LNG) has been developed since 1970s in order to satisfy various assignments including demands for higher efficiency and larger capacity. In order to satisfy these demands, i.e., to increase the efficiency and capacity of the liquefaction process, various attempts to liquefy natural gas by using different refrigerants or different cycles have been continuously conducted up to now. However, the number of liquefaction processes that are practically used is very small.

[0003] One of the liquefaction processes that are being operated and have been most widely used is a 'propane pre-cooled mixed refrigerant process (or a C3/MR process)'. As illustrated in FIG. 12, in the C3/MR process, natural gas (NG) is pre-cooled up to approximately 238 K through a Joule-Thomson (JT) cycle (or a propane cycle) using a propane refrigerant C3. Then, the pre-cooled natural gas is liquefied and sub-cooled up to approximately 123 K through a mixed refrigerant cycle using a mixed refrigerant (MR) or a multi-component refrigerant. As described above, since the C3/MR process uses a refrigeration cycle using a single refrigerant and a refrigeration cycle using a mixed refrigerant, the liquefaction process is complex, and also it is difficult to operate the liquefaction process.

[0004] Another one of the liquefaction processes that are being operated is a cascade process by Conoco Phillips Company. As illustrated in FIG. 13, the liquefaction process by Conoco Phillips Company consists of three Joule-Thomson cycles using methane C1, ethylene C2, and propane C3. As described above, since the cascade process uses only the refrigeration cycle using the single refrigerant, the liquefaction process is simplified in operation and improved in reliability. However, since an individual equipment (e.g., a heat exchanger) is needed for each of the three refrigeration cycles in the cascade process, there is a disadvantage that the liquefaction process needs to be increased in scale.

[0005] Another one of the liquefaction processes that are being operated is a 'single mixed refrigerant process (or SMR process)'. As illustrated in FIG. 14, in the SMR process, the natural gas is liquefied through a single closed-loop refrigeration cycle using the mixed refrigerant. The above-mentioned SMR process has an advantage that the liquefaction process is simplified in struc-

ture. However, the SMR process has a disadvantage in that the liquefaction process has low efficiency.

[0006] US 6,308,531 discloses a process according to the preamble of claim 1 for liquefied natural gas production. This process involves the compression of a gas to a high pressure, and then liquefying this gas against a cooling source. As a consequence, the resulting liquid expands to a low pressure. Since the resulting liquid then vaporizes, it provides refrigeration. This process does not involve two refrigerants that are compressed in parallel prior to being mixed.

DISCLOSURE OF THE INVENTION

TECHNICAL PROBLEM

[0007] To solve the above-described problems, an objective of the present invention is to provide a natural gas liquefaction process which is capable of being simplified in structure and being easily operated as well as having excellent efficiency.

TECHNICAL SOLUTION

[0008] A natural gas liquefaction process according to the present invention relates to a natural gas liquefaction process according to claim 1.

ADVANTAGEOUS EFFECTS

[0009] In the natural gas liquefaction process according to the present invention, since the single closed-loop refrigeration cycle using the mixed refrigerant is used, the liquefaction process may be simplified in structure and easily operated. In addition, since a single stream is separated into two streams, and then, each of the two streams cools the natural gas, the liquefaction process may have the excellent efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

FIG. 1 is a flowchart illustrating a natural gas liquefaction process according to Example Process 1 of the present description.

FIG. 2 is a flowchart illustrating a first modified example of the natural gas liquefaction process of FIG. 1.

FIG. 3 is a flowchart illustrating a second modified example of the natural gas liquefaction process of FIG. 1.

FIG. 4 is a flowchart illustrating a third modified example of the natural gas liquefaction process of FIG. 1.

FIG. 5 is a flowchart illustrating a fourth modified example of the natural gas liquefaction process of FIG. 1.

FIG. 6 is a flowchart illustrating a fifth modified example of the natural gas liquefaction process of FIG. 1, according to the present invention.

FIG. 7 is a flowchart illustrating a sixth modified example of the natural gas liquefaction process of FIG. 1.

FIG. 8 is a flowchart illustrating a natural gas liquefaction process according to the present invention.

FIG. 9 is a flowchart illustrating a modified embodiment of the natural gas liquefaction process of FIG. 8 according to the present invention.

FIG. 10 is a flowchart illustrating a natural gas liquefaction process according to an embodiment of the present invention.

FIG. 11 is a flowchart illustrating a modified embodiment of the natural gas liquefaction process of FIG. 10 according to the present invention.

FIG. 12 is a conceptual flowchart of a C3/MR process according to a related art.

FIG. 13 is a conceptual flowchart of a cascade process according to the related art.

FIG. 14 is a conceptual flowchart of an SMR process according to the related art.

MODE FOR CARRYING OUT THE INVENTION

[0011] Preferred example processes and embodiments of the present invention will be described below in more detail with reference to the accompanying drawings. However, the present invention is not limited to the embodiments below.

Example Process 1

[0012] FIG. 1 is a flowchart illustrating a natural gas liquefaction process according to Example Process 1 of the present description. A liquefaction process according to Example Process 1 of the present description, as illustrated in FIG. 1, may be applied to a process in which a single closed-loop refrigeration cycle is used to cool natural gas up to a liquefaction temperature, thereby producing liquefied natural gas (LNG). Particularly, the liquefaction process may be applied to a natural gas liquefaction process in which natural gas is primarily cooled in a first heat exchange part and then secondarily cooled in a second heat exchange part distinguished from the first heat exchange part by using a single closed-loop refrigeration cycle using a mixed refrigerant or multi-component refrigerant. In addition, the liquefaction process according to the current example may further include a refrigeration cycle for additionally cooling the mixed refrigerant or the natural gas.

[0013] Hereinafter, the liquefaction process according to Example 1 of the present description will be described in more detail with reference to FIG. 1. First, a mixed refrigerant (a main stream that will be described below) is partially condensed (a condensation step). That is, the mixed refrigerant is partially condensed through a series

of compression processes. Thus, the mixed refrigerant includes a liquid phase refrigerant and a gas phase refrigerant. Then, the mixed refrigerant is introduced into a separation unit 111 and separated into a first stream having a liquid phase and a second stream having a gas phase (a first separation step). Here, the separation unit 111 may be a normal vapor-liquid separator. This may be equally applied to a different separation unit that will be described below.

[0014] The first stream is introduced into a first heat exchange part 121 through a conduit 211 (a first introduction step). Then, the first stream is discharged from the first heat exchange part 121 and then introduced into an expansion unit 131 and expanded (a first expansion step). Thus, the first stream decreases in temperature. The expansion unit may include a Joule-Thomson (J-T) valve. For example, the expansion unit may include a normal expansion valve. Alternatively, the expansion unit may include an expander. This may be equally applied to a different expansion unit that will be described below. The J-T valve may reduce all of a pressure and a temperature of the stream through a J-T effect.

[0015] The first stream decreases in temperature due to the expansion and is introduced again into the first heat exchange part 121 through a conduit 212 to cool the natural gas (NG) in the first heat exchange part 121 (a first cooling step). The first stream introduced into the first heat exchange part 121 through the conduit 212 cools the natural gas together with the first stream introduced into the first heat exchange part 121 through the conduit 211 and the second stream introduced into the first heat exchange part 121 through a conduit 221. The natural gas may be pre-cooled through the above-described cooling. As described above, the first stream performs the cooling in the first heat exchange part 121 and then is recovered from the first heat exchange part 121 (a first recovery step). The first stream is recovered from the first heat exchange part 121 and then transferred for the condensation step through the conduit 213.

[0016] The second stream is introduced into the first heat exchange part 121 through the conduit 221 (a second introduction step). In the first heat exchange part 121, the second stream is cooled by the first stream introduced into the first heat exchange part 121 through the conduit 212. Then, the second stream is introduced into a second heat exchange part 122 through a conduit 222 (a third introduction step). Then, the second stream is discharged from the second heat exchange part 122 and then introduced into the expansion unit 132 and expanded (a second expansion step). Thus, the second stream decreases in temperature through the above-described expansion.

[0017] The second stream decreases in temperature due to the expansion and is introduced again into the second heat exchange part 122 through a conduit 223 to cool the natural gas in the second heat exchange part 122 (a second cooling step). The natural gas may be liquefied through the above-described cooling. As de-

scribed above, the second stream performs the cooling in the second heat exchange part 122 and then is recovered from the second heat exchange part 122 (a second recovery step). The second stream is recovered from the second heat exchange part 122 and then transferred for the condensation step through a conduit 224.

[0018] For reference, it is preferable that the first heat exchange part 121 includes a spiral wound heat exchanger (SWHE)-type heat exchanger. This may be equally applied to the second heat exchange part 122. In more detail, in case of the natural gas liquefaction process, a plate fin heat exchanger (PFHE)-type heat exchanger or a spiral wound heat exchanger (SWHE)-type heat exchanger is generally used for the heat exchanging. In case of the PFHE-type heat exchanger, a stream for cooling a different stream may be provided in plurality, and a stream cooled by a different stream may be provided in plurality. On the other hand, in case of the SWHE-type heat exchanger, a stream for cooling a different stream is provided in one, or a stream cooled by a different stream is provided in one.

[0019] Thus, the liquefaction process using the SWHE-type heat exchanger may be different from that using the PFHE-type heat exchanger. That is, the liquefaction process based on the PFHE-type heat exchanger may not be applied to that using the SWHE-type heat exchanger as it is. In case of the current example a single stream (a main stream that will be described below) is separated into two streams (a first stream and a second stream), and then the two streams are respectively used for cooling the natural gas in the first and second heat exchange parts 121 and 122. Thus, in case of the current embodiment, it is necessary to distinguish the first heat exchange part 121 from the second heat exchange part 122 so as to use the SWHE-type heat exchanger. That is, the first heat exchange part 121 may be provided as one SWHE-type heat exchanger, and the second heat exchange part 122 may be provided as the other SWHE-type heat exchanger. In addition, the SWHE-type heat exchanger is advantageous when a liquefaction system has large capacity. Also, the SWHE-type heat exchanger is advantageous for maintaining and repairing the liquefaction system.

[0020] As described above, in the liquefaction process according to the current example, the natural gas is liquefied by using the single closed-loop refrigeration cycle. Thus, the liquefaction process according to the current embodiment has advantages in that the liquefaction process is simplified in structure and easily operated. Also, in the liquefaction process according to the current embodiment, a single stream is separated into two streams, and then, each of the two streams cools the natural gas. Thus, although the liquefaction process according to the current example includes a single refrigeration cycle, the liquefaction process may have an effect as if the natural gas is cooled through two refrigeration cycles. As a result, the liquefaction process may have excellent efficiency.

[0021] The condensation step may be described in

more detail as follows. The second stream is recovered from the second heat exchange part 122 and then introduced into a compression unit 141 through a conduit 224 and compressed (a first compression step). Here, the compression unit 141 may be a normal compressor. Alternatively, the compression unit 141 may be a multi-stage compressor. This may be equally applied to a different compression unit that will be described below. Then, the second stream is introduced into a cooling unit 151 through a conduit 231 and cooled. Here, the cooling unit 151 may be a water cooling type or air cooling type cooler. This may be equally applied to a different cooling unit that will be described below. Here, the cooling unit 151 may be selectively provided. That is, the cooling unit 151 may be provided when it is necessary to cool the compressed stream. This may be equally applied to a different cooling unit.

[0022] The second stream is mixed with the first stream after the above-described cooling. That is, the first stream is recovered from the first heat exchange part 121 and then mixed with the second stream (a first mixing step). The above-described mixing may be achieved by connecting on conduit 213 to the other conduit 232. Alternatively, a separate constituent for the mixing may be provided. The main stream may be formed through the mixing. That is, the main stream may be a stream in which the first stream and the second stream are mixed with each other. The main stream is compressed by a compression unit 142 (a second compression step). Then, the main stream is introduced into a cooling unit 152 through a conduit 233 and cooled. The main stream is partially condensed through the series of processes and introduced into a separation unit 111 through a conduit 234.

[0023] For reference, the mixing may be a relative concept. That is, the first and second streams may be mixed with each other, or the second stream may be mixed with the first stream according to the structure of the conduit. Also, the first and second streams may be independently introduced into the compression unit 142 and then mixed with each other in the compression unit 142. Also, the above-described conduits may be different from each other or the same according to the reference numerals. That is, for convenience of description, two reference numerals may be given to only one conduit. On the other hand, for convenience of description, only one reference numeral may be given to two conduits.

[0024] The liquefaction process according to the current example may be modified as illustrated in FIG. 2. FIG. 2 is a flowchart illustrating a first modified example of the natural gas liquefaction process of FIG. 1. As illustrated in FIG. 2, in the liquefaction process according to the modified example, the condensation process basically further includes a third compression step and a fourth compression step. In more detail, a main stream in the liquefaction process according to the modified example is cooled by a cooling unit 152 and then introduced into a compression unit 143 through a conduit 2341 and

compressed (a third compression step). Then, the main stream is introduced into a cooling unit 153 through a conduit 2342 and cooled.

[0025] Then, the main stream is introduced into a separation unit 112 through a conduit 2343 and then separated into a third stream having a liquid phase and a fourth stream having a gas phase (a second separation step). Then, the third stream is mixed with the main stream within the conduit 2341 through a conduit 2344 (a second mixing step). Here, the third stream is expanded by an expansion unit and then mixed with the main stream. Then, the third stream is introduced into the compression unit 143 together with the main stream. Also, the fourth stream is introduced into a compression unit 144 through a conduit 2345 and compressed (a fourth compression step). Then, the fourth stream is introduced into a cooling unit 154 through a conduit 2346 and cooled. The fourth stream is partially condensed through the series of processes and introduced into a separation unit 111 through a conduit 2347.

[0026] Here, it is preferable that the compression unit (for example, the compression unit expressed by reference numeral 144) receives a gas refrigerant. However, when the refrigerant is mixed, or the refrigerant is compressed or cooled like the mixture of the first and second streams, a liquid refrigerant may be generated. Thus, when the separation unit 112 is used as described in the modified example, only the gas refrigerant may be supplied into the compression unit.

[0027] Also, the liquefaction process according to the current example may be modified as illustrated in FIG. 3. FIG. 3 is a flowchart illustrating a second modified example of the natural gas liquefaction process of FIG. 1. As illustrated in FIG. 3, the second stream is recovered from the second heat exchange part 122 and then introduced into a compression unit 141 through a conduit 224 and compressed (a first compression step). Then, the second stream is introduced into a cooling unit 151 through a conduit 231 and cooled.

[0028] The second stream is mixed with the first stream after the cooling. That is, the first stream is recovered from the first heat exchange part 121 and then mixed with the second stream (a first mixing step). The main stream may be formed through the mixing. As described above, the main stream is introduced into a separation unit 112 through a conduit 2321 and then separated into a third stream having a liquid phase and a fourth stream having a gas phase (a second separation step). The fourth stream is introduced into a compression unit 142 through a conduit 2322 and compressed (a second compression step). Then, the fourth stream is mixed with the third stream (a second mixing step). Here, the third stream may be forcibly transferred into a conduit 2324 by a pump 161. Then, the third stream and the fourth stream (the main stream) are introduced into a cooling unit 152 through a conduit 2324 and cooled. The main stream is partially condensed through the series of processes and introduced into a separation unit 111 through

a conduit 234. The liquid refrigerant which may be generated while the refrigerant is compressed may be increased in pressure by using a refrigerant pump because the liquid refrigerant is not increased in pressure by using a refrigerant compressor.

[0029] Also, the liquefaction process according to the current example may be modified as illustrated in FIG. 4. FIG. 4 is a flowchart illustrating a first modified example of the natural gas liquefaction process of FIG. 1. As illustrated in FIG. 4, in the liquefaction process according to the modified example, a compression unit 1411 may be further provided. In more detail, when the first and second streams are mixed with each other to form a main stream, the main stream is introduced into the compression unit 1411 through a conduit 1231 and compressed. Then, the main stream is introduced into a cooling unit 1511 through a conduit 1232 and cooled. Then, the main stream is introduced into a separation unit 112 through a conduit 1233. The liquid refrigerant which may be generated while the refrigerant is additionally compressed may be increased in pressure by using a refrigerant pump, like the additional compression stage as described in the modified example, because the liquid refrigerant is not increased in pressure by using a refrigerant compressor.

[0030] Furthermore, the liquefaction process according to the current example may be modified as illustrated in FIG. 5. FIG. 5 is a flowchart illustrating a first modified example of the natural gas liquefaction process of FIG. 1. As illustrated in FIG. 5, in the liquefaction process according to the modified example, the second stream is recovered from the second heat exchange part 122 and then introduced into a compression unit 141 through a conduit 224 and compressed (a first compression step). Then, the second stream is introduced into a cooling unit 151 through a conduit 231 and cooled. Also, the first stream is recovered from the first heat exchange part 121 and then introduced into a compression unit 142 through a conduit 213 and compressed (a second compression step). Then, the first stream is introduced into a cooling unit 152 through a conduit 291 and cooled.

[0031] Then, the first stream is mixed with the second stream within the conduit 292 through a conduit 232 (a first mixing step). The main stream may be formed through the mixing. That is, the main stream may be a stream in which the first stream and the second stream are mixed with each other. The main stream is compressed by the compression unit 143 (a third compression step). Then, the main stream is introduced into a cooling unit 153 through a conduit 233 and cooled. The main stream is partially condensed through the series of processes and introduced into a separation unit 111 through a conduit 234.

[0032] In the liquefaction process according to the modified example, the main stream is separated into the first and second streams by the separation unit 111, and then, the first and second streams are not mixed with each other until the first and second streams are compressed by the compression units 141 and 142. Thus,

conditions different from each other (for example, pressure conditions) may be applied to the first and second streams. Therefore, the liquefaction process according to the modified example may be very advantageous for optimizing the liquefaction process.

[0033] According to the present invention, the liquefaction process according to the current example may be modified as illustrated in FIG. 6. FIG. 6 is a flowchart illustrating a fifth modified example of the natural gas liquefaction process of FIG. 1. As illustrated in FIG. 6, in the liquefaction process according to the modified example, the second stream is recovered from the second heat exchange part 122 and then introduced into a compression unit 141 through a conduit 224 and compressed (a first compression step). Then, the second stream is introduced into a cooling unit 151 through a conduit 241 and cooled. Also, the first stream is recovered from the first heat exchange part 121 and then introduced into a compression unit 142 through a conduit 213 and compressed (a second compression step). Then, the first stream is introduced into a cooling unit 152 through a conduit 251 and cooled. Also, the second stream is introduced into a compression unit 143 through a conduit 242 and compressed (a third compression step). Then, the second stream is introduced into a cooling unit 153 through a conduit 243 and cooled.

[0034] Then, the second stream is mixed with the first stream. That is, the first stream is mixed with the second stream within the conduit 252 through a conduit 244 (a first mixing step). The main stream may be formed through the mixing. As described above, the main stream is introduced into a separation unit 112 and then separated into a third stream having a liquid phase and a fourth stream having a gas phase (a second separation step). Then, the third stream is mixed with the second stream within the conduit 245 through a conduit 242 (a second mixing step). Here, the third stream is expanded by an expansion unit and then mixed with the second stream. Then, the third stream is introduced into the compression unit 143 together with the second stream. Also, the fourth stream is introduced into a compression unit 144 through a conduit 246 and compressed (a fourth compression step). Then, the fourth stream is introduced into a cooling unit 154 through a conduit 247 and cooled. The fourth stream is partially condensed through the series of processes and introduced into a separation unit 111 through a conduit 248.

[0035] The liquefaction process according to the modified example may have the same characteristics as that according to the foregoing fourth modified example. That is, in the liquefaction process according to the modified example, the fourth stream is separated into the first and second streams by the separation unit, and then, the first and second streams are not mixed with each other until the first and second streams are compressed by the compression unit. In addition, the liquefaction process according to the modified example may have the same characteristics as that according to the foregoing first mod-

ified example. That is, in the liquefaction process according to the modified example, only the gas refrigerant may be supplied by using the compression unit.

[0036] Furthermore, the liquefaction process according to the current example may be modified as illustrated in FIG. 7. FIG. 7 is a flowchart illustrating a sixth modified example of the natural gas liquefaction process of FIG. 1. As illustrated in FIG. 7, in the liquefaction process according to the modified example, the second stream is recovered from the second heat exchange part 122 and then introduced into a compression unit 141 through a conduit 224 and compressed (a first compression step). Then, the second stream is introduced into a cooling unit 151 through a conduit 231 and cooled. Also, the first stream is recovered from the first heat exchange part 121 and then introduced into a compression unit 142 through a conduit 213 and compressed (a second compression step). Then, the first stream is introduced into a cooling unit 152 through a conduit 291 and cooled.

[0037] Then, the first stream is mixed with the second stream within the conduit 292 through a conduit 2331 (a first mixing step). The main stream may be formed through the mixing. The main stream is introduced into a separation unit 112 and then separated into a third stream having a liquid phase and a fourth stream having a gas phase (a second separation step). The fourth stream is introduced into a compression unit 143 through a conduit 2332 and compressed (a third compression step). Then, the fourth stream is mixed with the third stream (a second mixing step). Here, the third stream may be forcibly transferred into a conduit 2334 by a pump 161. Then, the main stream is introduced into a cooling unit 153 through a conduit 2334 and cooled. The main stream is partially condensed through the series of processes and introduced into a separation unit 111 through a conduit 234. A compressor has to be used for increasing a pressure of the refrigerant mixed in the first mixing step. However, if the liquid refrigerant is generated in the first mixing step, it is impossible to directly introduce the liquid refrigerant into the compressor. Thus, the generated liquid refrigerant has to be separated and then increased in pressure by using the pump.

[0038] FIG. 8 is a flowchart illustrating a natural gas liquefaction process according to the present invention. As illustrated in FIG. 8, the liquefaction process according to the current embodiment may be similar to that according to the foregoing Example 1, particularly, the fifth modified example. However, the liquefaction process according to the current embodiment is the same as the foregoing fifth modified example except for a third heat exchange part. For reference, the same (equivalent) component as that according to the foregoing embodiment is given by the same (equivalent) reference number, and thus, their detailed description will be omitted.

[0039] As illustrated in FIG. 8, in the liquefaction process according to the current embodiment, a second stream is introduced into a third heat exchange part 123 through a conduit 2211 (a second introduction step). In

the third heat exchange part 123, the second stream is cooled by the second stream introduced into the third heat exchange part 123 through a conduit 2214. Then, the second stream is introduced into a second heat exchange part 122 through a conduit 2212 (a third introduction step). Then, the second stream is discharged from the second heat exchange part 122 and then introduced into an expansion unit 132 and expanded (a second expansion step). Thus, the second stream decreases in temperature through the above-described expansion.

[0040] The second stream decreases in temperature due to the expansion and is introduced again into the second heat exchange part 122 through a conduit 2213 to cool natural gas in the second heat exchange part 122 (a second cooling step). The natural gas may be liquefied through the above-described cooling. As described above, the second stream performs the cooling in the second heat exchange part 122 and then is recovered from the second heat exchange part 122 through a conduit 2214 and introduced again into the third heat exchange part 123 (a fourth introduction step). The second stream may have some cool energy after the natural gas is cooled in the second heat exchange part 122. Thus, the liquefaction process according to the current embodiment is characterized in that the cool energy is used in the third heat exchange part 123. That is, in the third heat exchange part 123, the second stream cools the second stream introduced into the third heat exchange part 123 through the conduit 2211. The second stream performs the cooling in the second heat exchange part and then recovered from the third heat exchange part 123 (a second recovery step). The second stream is recovered from the third heat exchange part 123 and then transferred for the condensation step through a conduit 2215.

[0041] For reference, it is preferable that each of the first and second heat exchange parts 121 and 122 includes an SWHE-type heat exchanger. However, the third heat exchange part 123 may be an SWHE-type heat exchange or PFHE-type heat exchanger. That is, the third heat exchange part 123 is not particularly limited to the type of heat exchanger. However, the third heat exchange part 123 may be separately provided with respect to the first heat exchange part 121. (The third heat exchange part may be integrated with the second heat exchange part)

[0042] The liquefaction process according to the current invention may be modified as illustrated in FIG. 9. FIG. 9 is a flowchart illustrating a modified embodiment of the natural gas liquefaction process of FIG. 8. As illustrated in FIG. 9, in the liquefaction process according to the modified embodiment, the second stream is separated into a first portion and a second portion. The above-described branch may be achieved by branching the other conduit 2216 from one conduit 2211. Alternatively, a separate constituent for the branch may be provided.

[0043] Here, the first portion may be introduced into the third heat exchange part 123. That is, in the liquefac-

tion process according to the present invention the whole second stream is supplied into the third heat exchange part 123. However, in the liquefaction process according to the modified embodiment, only a portion of the second stream is supplied into the third heat exchange 123. Also, the second portion is introduced into the first heat exchange part 121 through a conduit 2216. Here, the second portion is cooled by the first stream introduced into the first heat exchange part 121 through the conduit 212. Then, the first and second portions are mixed again with each other and then introduced into the second heat exchange part 122 (see the conduits 2212 and 2217).

[0044] In the liquefaction process according to the modified embodiment, the first portion of the second stream is cooled in the third heat exchange part 123, and the second portion of the second stream is cooled in the first heat exchange part 121. That is, in the liquefaction process according to the modified embodiment, the second stream is separated into the two portions, and then, the two portions are respectively cooled in the heat exchange parts different from each other. Thus, the liquefaction process according to the modified example, it is unnecessary to cool the whole second stream in the third heat exchange part 123. Therefore, the liquefaction process according to the modified embodiment may be suitable when it is difficult to cool the whole second stream in the third heat exchange part 123.

[0045] FIG. 10 is a flowchart illustrating a natural gas liquefaction process according to the present invention. As illustrated in FIG. 10, the liquefaction process according to the current embodiment may be similar to that according to the foregoing Example 1, particularly, the fifth modified example. However, the liquefaction process according to the current embodiment is the same as the foregoing fifth modified example except for a third heat exchange part. For reference, the same (equivalent) component as that according to the foregoing embodiment is given by the same (equivalent) reference number, and thus, their detailed description will be omitted.

[0046] As illustrated in FIG. 10, in the liquefaction process according to the current embodiment, a second stream is introduced into a first heat exchange part 121 through a conduit 2311 (a second introduction step). In the first heat exchange part 121, the second stream is cooled by a first stream introduced into the first heat exchange part 121 through a conduit 212. Then, the second stream is introduced into a second heat exchange part 122 through a conduit 2312 (a third introduction step). Then, the second stream is discharged from the second heat exchange part 122 and then introduced into an expansion unit 132 and expanded (a second expansion step). Thus, the second stream decreases in temperature through the above-described expansion.

[0047] The second stream decreases in temperature due to the expansion and is introduced again into the second heat exchange part 122 through a conduit 2313 to cool natural gas in the second heat exchange part 122

(a second cooling step). The natural gas may be liquefied through the above-described cooling. As described above, the second stream performs the cooling in the second heat exchange part 122 and then is recovered from the second heat exchange part 122 through a conduit 2314 and introduced into the third heat exchange part 123. The second stream may have some cool energy after the natural gas is cooled in the second heat exchange part 122. Thus, the liquefaction process according to the current embodiment is characterized in that the cool energy is used in the third heat exchange part 123. That is, in the third heat exchange part 123, the second stream cools the natural gas introduced into the third heat exchange part 123 through a conduit 311 (a third cooling step). The natural gas may be pre-cooled through the above-described cooling. The second stream performs the cooling in the second heat exchange part and then is recovered from the third heat exchange part 123 (a second recovery step). The second stream is recovered from the third heat exchange part 123 and then transferred for the condensation step through a conduit 2315.

[0048] As described above, the natural gas is primarily cooled in the third heat exchange part 123 and then supplied into the second heat exchange part 122 through a conduit 312. Then, the natural gas is secondarily cooled in the second heat exchange part 122. As a result, the natural gas may be liquefied. For reference, it is preferable that each of the first and second heat exchange parts 121 and 122 includes an SWHE-type heat exchanger. However, the third heat exchange part 123 may be an SWHE-type heat exchange or PFHE-type heat exchanger. That is, the third heat exchange part 123 is not particularly limited to the type of heat exchanger. However, the third heat exchange part 123 may be separately provided with respect to the first heat exchange part 121. (The third heat exchange part may be integrated with the second heat exchange part)

[0049] The liquefaction process according to the current embodiment may be modified as illustrated in FIG. 11. FIG. 11 is a flowchart illustrating a modified embodiment of the natural gas liquefaction process of FIG. 10. As illustrated in FIG. 11, in the liquefaction process according to the modified example, the natural gas is separated into a first portion and a second portion. The above-described branch may be achieved by branching one conduit into two conduits. Alternatively, a separate constituent for the branch may be provided.

[0050] Here, the first portion may be introduced into the third heat exchange part 123. That is, in the liquefaction process according to Embodiment 3, the whole natural gas is supplied into the third heat exchange part 123. However, in the liquefaction process according to the modified example, only a portion of the natural gas is supplied into the third heat exchange 123. Also, the second portion is introduced into the first heat exchange part 121 through a conduit 313. Here, the second portion is cooled by the first stream introduced into the first heat exchange part 121 through the conduit 212. Then, the

first and second portions are mixed again with each other and then introduced together into the second heat exchange part 122 (see the conduits 312 and 314).

[0051] In the liquefaction process according to the modified example, the first portion of the natural gas is cooled in the third heat exchange part 123, and the second portion of the natural gas is cooled in the first heat exchange part 121. That is, the liquefaction process according to the modified example is characterized in that the natural gas is separated into the two portions, and then, the two portions are respectively cooled (pre-cooled) in the heat exchange parts different from each other.

Claims

1. A natural gas liquefaction process in which natural gas is primarily cooled in a first heat exchange part (121) and secondarily cooled in a second heat exchange part (122) distinguished from the first heat exchange part (121) by using a single closed-loop refrigeration cycle using a mixed refrigerant, the closed-loop refrigeration cycle comprising:
 - a condensation step of partially condensing the mixed refrigerant;
 - a first separation step (111) of separating the mixed refrigerant into a first stream (211) having a liquid phase and a second stream (221) having a gas phase after the condensation step;
 - a first introduction step (211) of introducing the first stream into the first heat exchange part (121) after the first separation step;
 - a first expansion step (131) of expanding the first stream discharged from the first heat exchange part (121) after the first introduction step (211);
 - a first cooling step of introducing the first stream again into the first heat exchange part (121) to cool the natural gas in the first heat exchange part (121) through the first stream after the first expansion step (131);
 - a first recovery step of recovering the first stream from the first heat exchange part (121) after the first cooling step;
 - a second introduction step (221) of introducing the second stream into the first heat exchange part (121) after the first separation step (111);
 - a third introduction step (222) of introducing the second stream discharged from the first heat exchange part (121) into the second heat exchange part (122) after the second introduction step (221);
 - a second expansion step (132) of expanding the second stream discharged from the second heat exchange part (122) after the third introduction step (222);
 - a second cooling step of introducing the second stream again into the second heat exchange part (122) to cool the natural gas in the second heat ex-

change part (122) through the second stream after the second expansion step; and

a second recovery step of recovering the second stream from the second heat exchange part (122) after the second cooling step (132),

wherein the first stream is transferred for the condensation step after the first recovery step, and the second stream is transferred for the condensation step after the second recovery step; **characterized in that** the condensation step comprises:

a first compression step (141) of compressing the second stream (224);

a second compression step (142) of compressing the first stream (213);

a third compression step (143) of compressing the second stream after the first compression step (141);

a first mixing step of mixing the first stream with the second stream to form a main stream after the second (142) and third (143) compression steps;

a second separation step (112) of separating the main stream into a third stream (245) having a liquid phase and a fourth stream (246) having a gas phase after the first mixing step;

a second mixing step of mixing the third stream (245) with the second stream (241) after the second separation step (112); and

a fourth compression step (144) of compressing the fourth stream (246) after the second separation step (112),

wherein the third stream (245) is transferred for the third compression step (143) together with the second stream (241) after the second mixing step (242), and the fourth stream (247)

is transferred for the first separation step (111) after the fourth compression step (144).

2. The natural gas liquefaction process of claim 1, wherein each of the first (121) and second (122) heat exchange parts comprises a spiral wound heat exchanger (SWHE)-type heat exchanger.

Patentansprüche

1. Ein Erdgasverflüssigungsverfahren, in dem das Erdgas in erster Linie in einem ersten Wärmetauscherabschnitt (121) gekühlt und in zweiter Linie in einem zweiten Wärmetauscherabschnitt (122) gekühlt wird, der sich vom ersten Wärmetauscherabschnitt (121) unterscheidet, indem ein einziger Kühlzyklus im geschlossenen Kreislauf unter Verwendung eines Kältemittelgemischs verwendet wird, wobei der Kühlzyklus im geschlossenen Kreislauf folgendes beinhaltet:

- Eine Kondensierungsetappe zur teilweisen Kondensierung des Kältemittelgemischs;

- Eine erste Etappe (111), wo das Kältemittelgemisch in einen ersten Strom (211) in der Form einer flüssigen Phase und in einen zweiten Strom (221) in der Form einer Gasphase nach der Kondensierungsetappe getrennt wird;

- Eine erste Einführungsetappe (211), wo der erste Strom in den ersten Wärmetauscherabschnitt (121) nach der ersten Trennungsetappe eingeführt wird;

- Eine erste Expansionsetappe (131), wo der erste, aus dem ersten Wärmetauscherabschnitt (121) nach der ersten Einführungsetappe (211) entladene erste Strom expandiert;

- Eine erste Kühletappe mit der erneuten Einführung des ersten Stroms in den ersten Wärmetauscherabschnitt (121) zur Kühlung des Erdgases im ersten Wärmetauscherabschnitt (121) durch den ersten Strom nach der ersten Expansionsetappe (131);

- Eine erste Etappe der Wiederherstellung des ersten Stroms aus dem ersten Wärmetauscherabschnitt (121) nach der ersten Kühletappe;

- Eine zweite Einführungsetappe (221), wo der zweite Strom in den ersten Wärmetauscherabschnitt (121) nach der ersten Trennungsetappe (111) eingeführt wird;

- Eine dritte Einführungsetappe (222), wo der zweite Strom aus dem ersten Wärmetauscherabschnitt (121) in den zweiten Wärmetauscherabschnitt (122) nach der zweiten Einführungsetappe (221) eingeführt wird;

- Eine zweite Expansionsetappe (132), wo der zweite, aus dem zweiten Wärmetauscherabschnitt (122) nach der dritten Einführungsetappe (222) entladene Strom expandiert;

- Eine zweite Kühletappe der erneuten Einführung des zweiten Stroms in den zweiten Wärmetauscherabschnitt (122) zur Kühlung des Erdgases im zweiten Wärmetauscherabschnitt (122) durch den zweiten Strom nach der zweiten Expansionsetappe (131); und

- Eine zweite Etappe der Wiederherstellung des zweiten Stroms aus dem zweiten Wärmetauscherabschnitt (122) nach der zweiten Kühletappe (132);

wobei der erste Strom zur Kondensierungsetappe nach der ersten Etappe der Wiederherstellung transferiert wird, und der zweite Strom zur Kondensierungsetappe nach der zweiten Etappe der Wiederherstellung transferiert wird, **dadurch gekennzeichnet, dass** die Kondensierungsetappe folgendes umfasst:

◦ Eine erste Verdichtungsetappe (141) zur Verdichtung des zweiten Stroms (224);

- Eine zweite Verdichtungsetappe (142) zur Verdichtung des ersten Stroms (213);
- Eine dritte Verdichtungsetappe (143) zur Verdichtung des zweiten Stroms nach der ersten Verdichtungsetappe (141);
- Eine erste Mischetappe, wo der erste Strom mit dem zweiten Strom gemischt werden, um nach den zweiten (142) und dritten (143) Verdichtungsetappen einen Hauptstrom zu bilden;
- Eine zweite Trennungsetappe (112) der Trennung des Hauptstroms in einen dritten Strom (245) in flüssiger Phase und einen vierten Strom (246) in einer Gasphase nach der ersten Mischetappe;
- Eine zweite Mischetappe zum Mischen des dritten Stroms (245) mit dem zweiten Strom (241) nach der zweiten Trennungsetappe (112); und
- Eine vierte Verdichtungsetappe (144) zur Verdichtung des vierten Stroms (246) nach der zweiten Trennungsetappe (112),

wobei der dritte Strom (245) zur dritten Verdichtungsphase (143) gemeinsam mit dem zweiten Strom (241) nach der zweiten Mischetappe (242) transferiert wird, und der vierte Strom (247) zur ersten Trennungsetappe (111) nach der vierten Verdichtungsetappe (144) transferiert wird.

2. Erdgasverflüssigungsverfahren gemäß Anspruch 1, wobei jeder der ersten (121) und zweiten (122) Wärmetauscherabschnitte einen spiralförmig gewundenen Wärmetauscher vom Typ Spiralwärmeübertrager (SWHET = Spiral Wound Heat Exchanger) umfasst.

Revendications

1. Procédé de liquéfaction de gaz naturel dans lequel un gaz naturel est principalement refroidi dans une première partie d'échange thermique (121) et secondairement refroidi dans une seconde partie d'échange thermique (122) distincte de la première partie d'échange thermique (121) en utilisant un cycle de réfrigération à boucle fermée unique utilisant un réfrigérant mixte, le cycle de réfrigération à boucle fermée comprenant :

une étape de condensation consistant à condenser partiellement le réfrigérant mixte ;
 une première étape de séparation (111) consistant à séparer le réfrigérant mixte en un premier courant (211) ayant une phase liquide et un deuxième courant (221) ayant une phase gazeuse après l'étape de condensation ;
 une première étape d'introduction (211) consistant à introduire le premier courant dans la pre-

mière partie d'échange de chaleur (121) après la première étape de séparation ;
 une première étape d'expansion (131) consistant à expander le premier courant déchargé de la première partie d'échange de chaleur (121) après la première étape d'introduction (211) ;
 une première étape de refroidissement consistant à réintroduire le premier courant dans la première partie d'échange de chaleur (121) pour refroidir le gaz naturel dans la première partie d'échange thermique (121) à travers le premier courant après la première étape d'expansion (131) ;
 une première étape de récupération consistant à récupérer le premier courant à partir de la première partie d'échange de chaleur (121) après la première étape de refroidissement ;
 une deuxième étape d'introduction (221) consistant à introduire le deuxième courant dans la première partie d'échange de chaleur (121) après la première étape de séparation (111) ;
 une troisième étape d'introduction (222) consistant à introduire le deuxième courant déchargé depuis la première partie d'échange thermique (121) dans la seconde partie d'échange thermique (122) après la deuxième étape d'introduction (221) ;
 une seconde étape d'expansion (132) consistant à expander le deuxième courant déchargé depuis la seconde partie d'échange de chaleur (122) après la troisième étape d'introduction (222) ;
 une seconde étape de refroidissement consistant à réintroduire le deuxième courant dans la seconde partie d'échange de chaleur (122) pour refroidir le gaz naturel dans la seconde partie d'échange de chaleur (122) à travers le deuxième courant après la seconde étape d'expansion ; et
 une seconde étape de récupération consistant à récupérer le deuxième courant depuis la seconde partie d'échange de chaleur (122) après la seconde étape de refroidissement (132),

dans lequel le premier courant est transféré pour l'étape de condensation après la première étape de récupération, et le deuxième courant est transféré pour l'étape de condensation après la seconde étape de récupération ; **caractérisé en ce que** l'étape de condensation comprend :

une première étape de compression (141) consistant à comprimer le deuxième courant (224) ;
 une deuxième étape de compression (142) consistant à comprimer le premier courant (213) ;
 une troisième étape de compression (143) consistant à comprimer le deuxième courant après la première étape de compression (141) ;

une première étape de mélange consistant à mélanger le premier courant avec le deuxième courant pour former un courant principal après les deuxième (142) et troisième (143) étapes de compression ;
une seconde étape de séparation (112) consistant à séparer le courant principal en un troisième courant (245) ayant une phase liquide et en un quatrième courant (246) ayant une phase gazeuse après la première étape de mélange ;
une seconde étape de mélange consistant à mélanger le troisième courant (245) avec le deuxième courant (241) après la seconde étape de séparation (112) ; et
une quatrième étape de compression (144) consistant à comprimer le quatrième courant (246) après la seconde étape de séparation (112), dans lequel le troisième courant (245) est transféré pour la troisième étape de compression (143) ensemble avec le deuxième courant (241) après la seconde étape de mélange (242), et le quatrième courant (247) est transféré pour la première étape de séparation (111) après la quatrième étape de compression (144).

2. Procédé de liquéfaction de gaz naturel selon la revendication 1, dans lequel chacune des première (121) et seconde (122) parties d'échange de chaleur comprend un échangeur de chaleur du type échangeur de chaleur à enroulement en spirale (SWHE).

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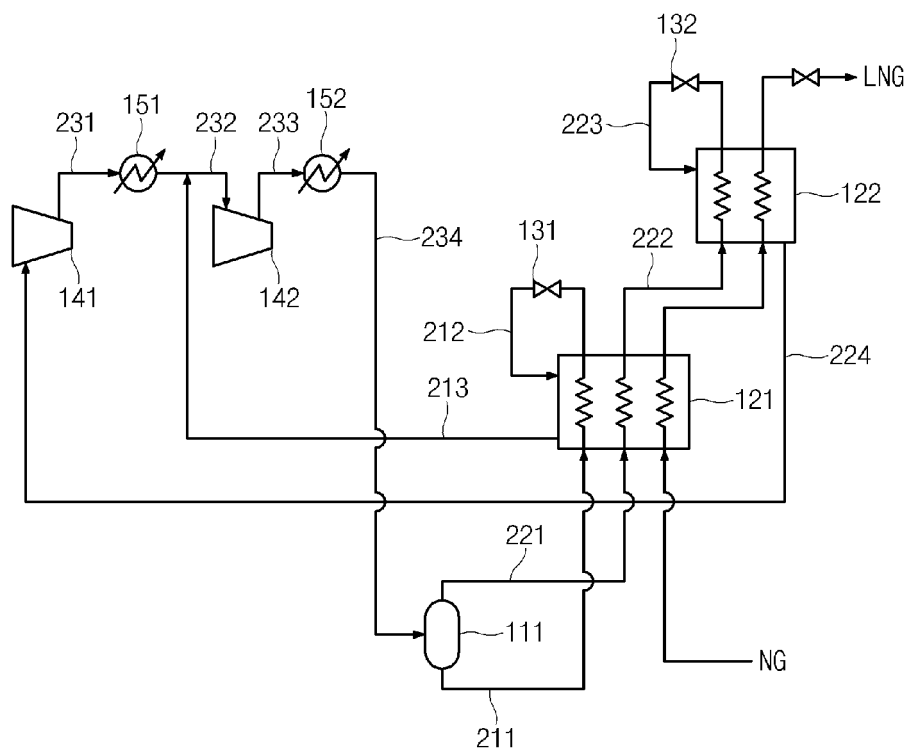
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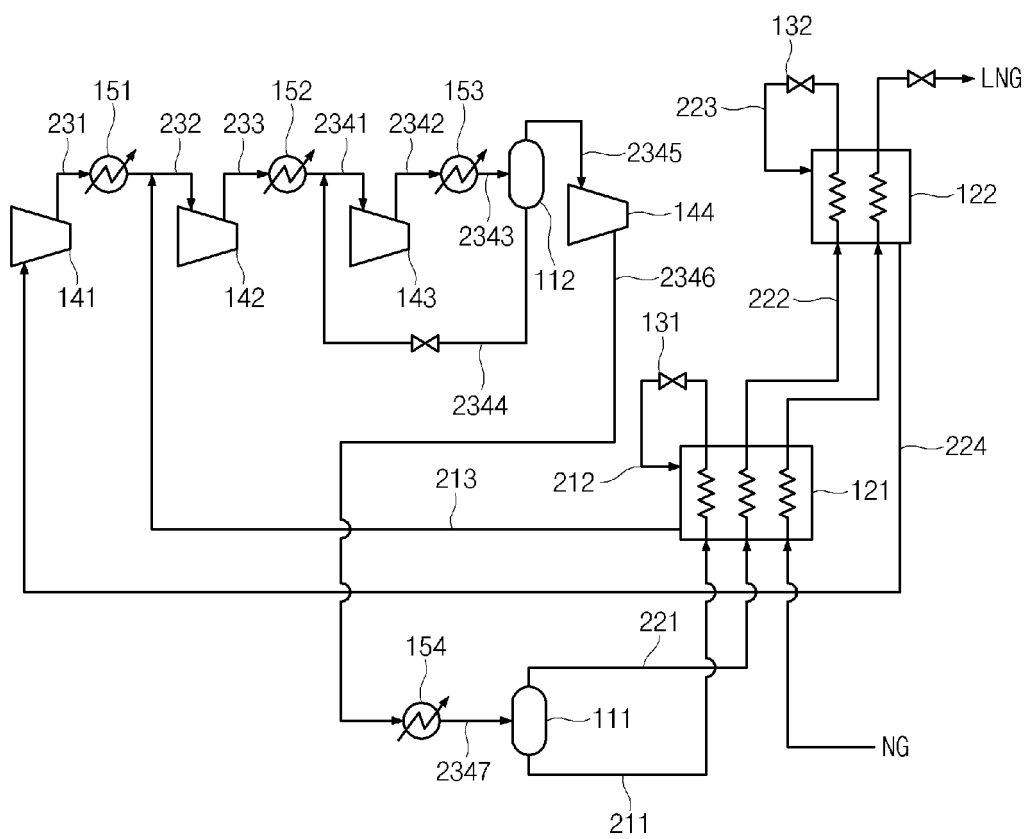
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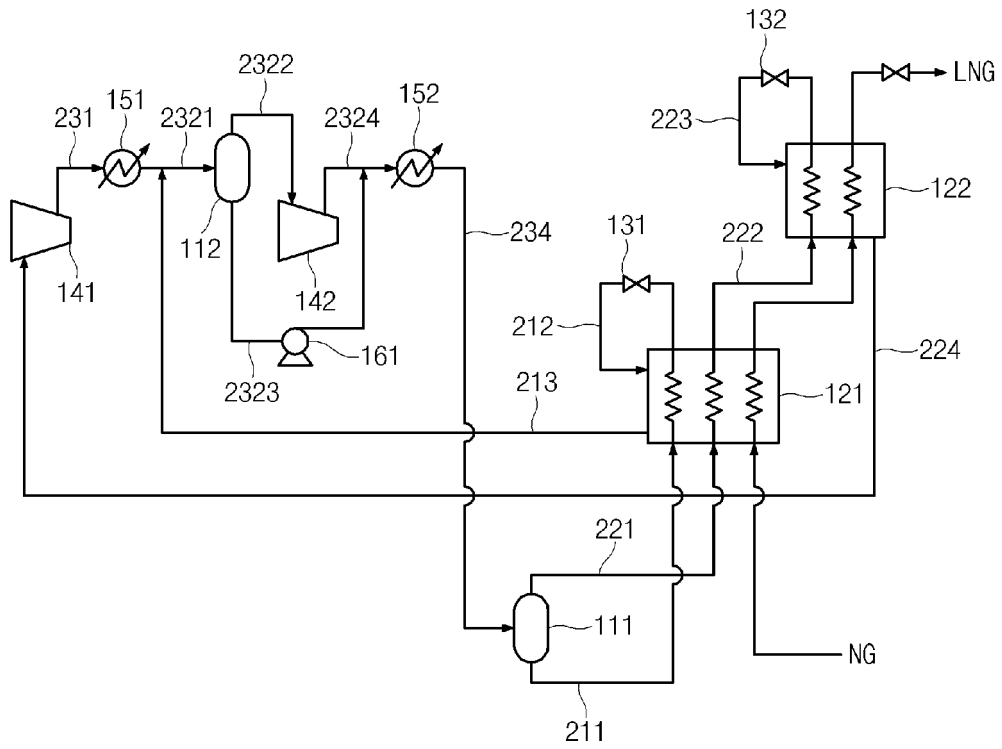
[Fig. 1]



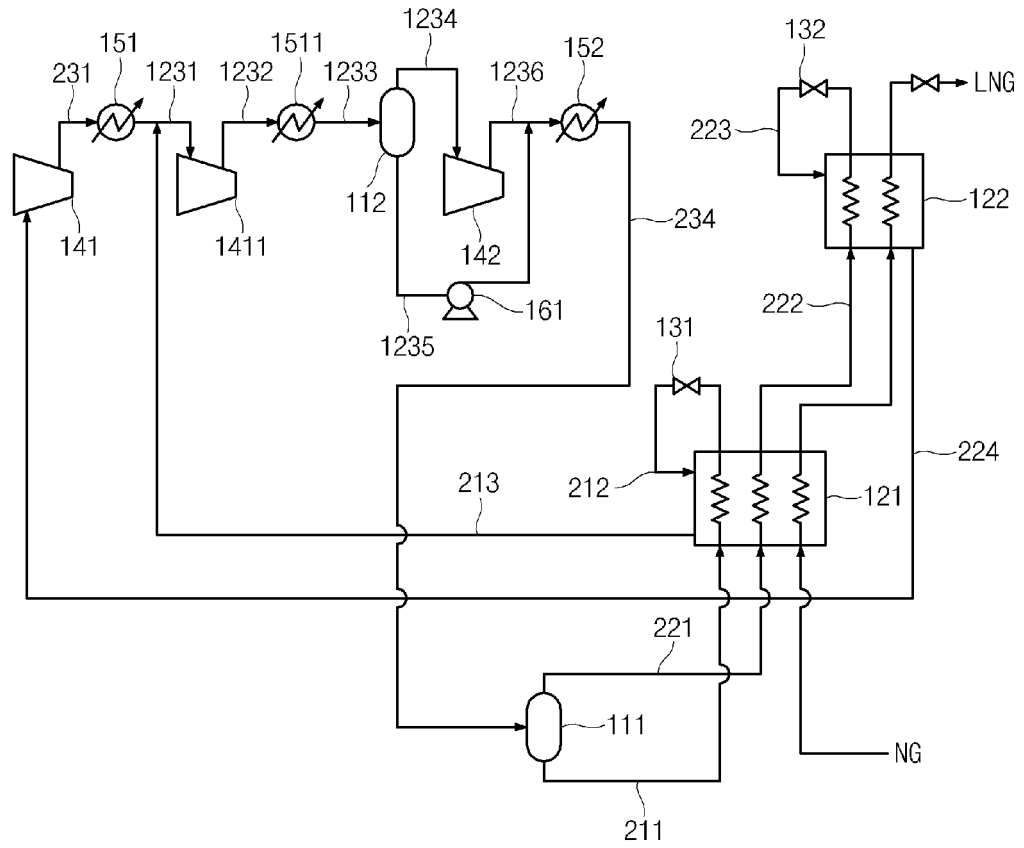
[Fig. 2]



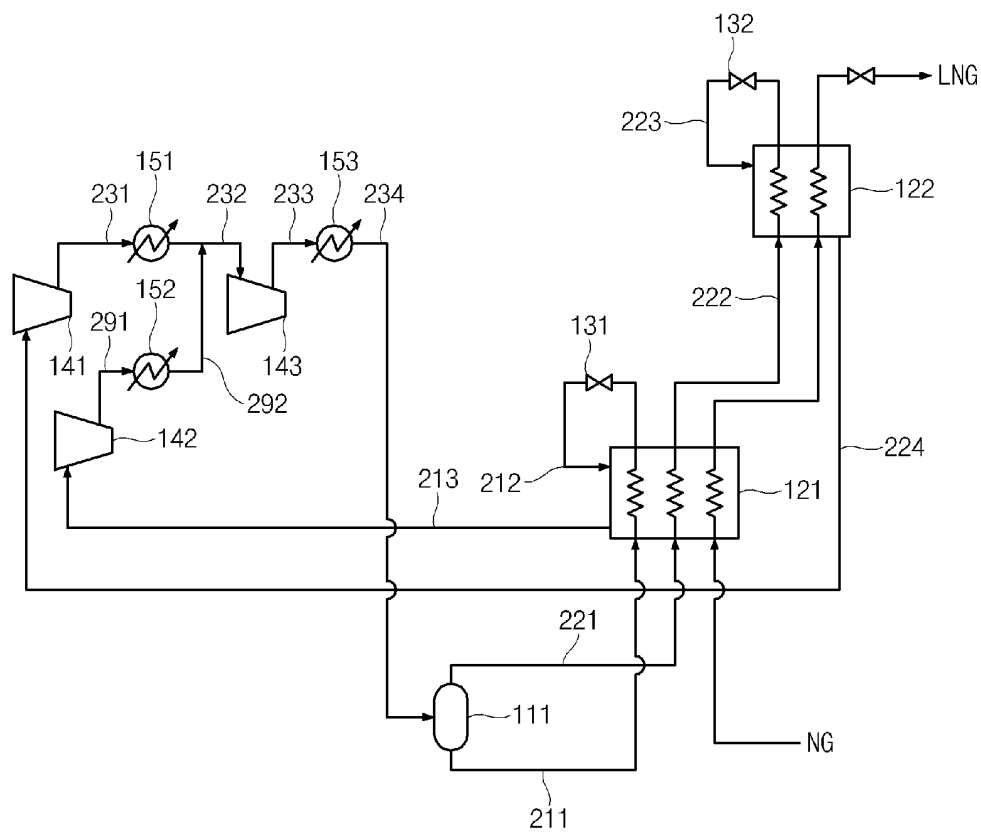
[Fig. 3]



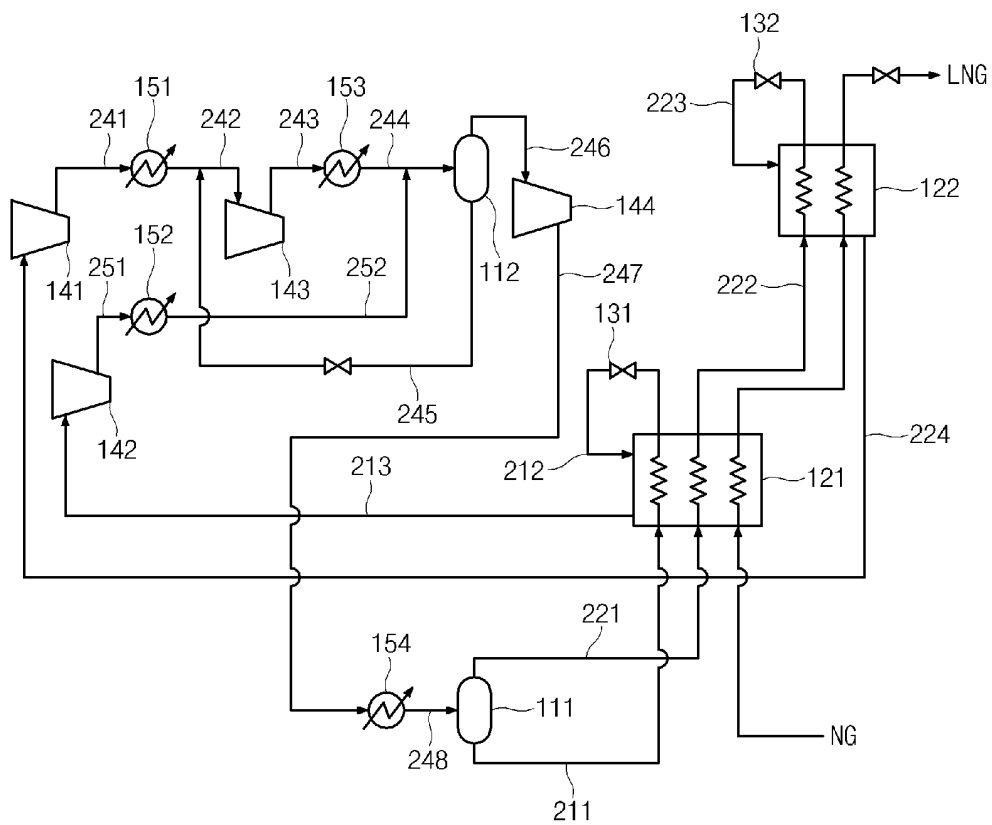
[Fig. 4]



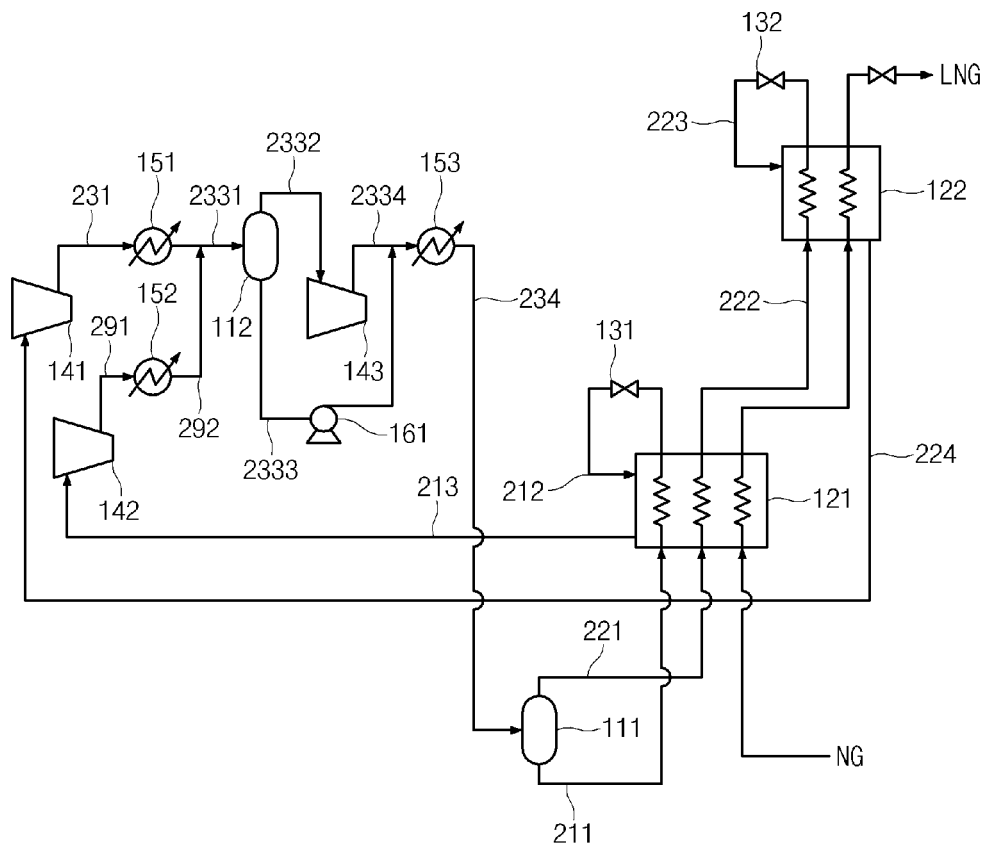
[Fig. 5]



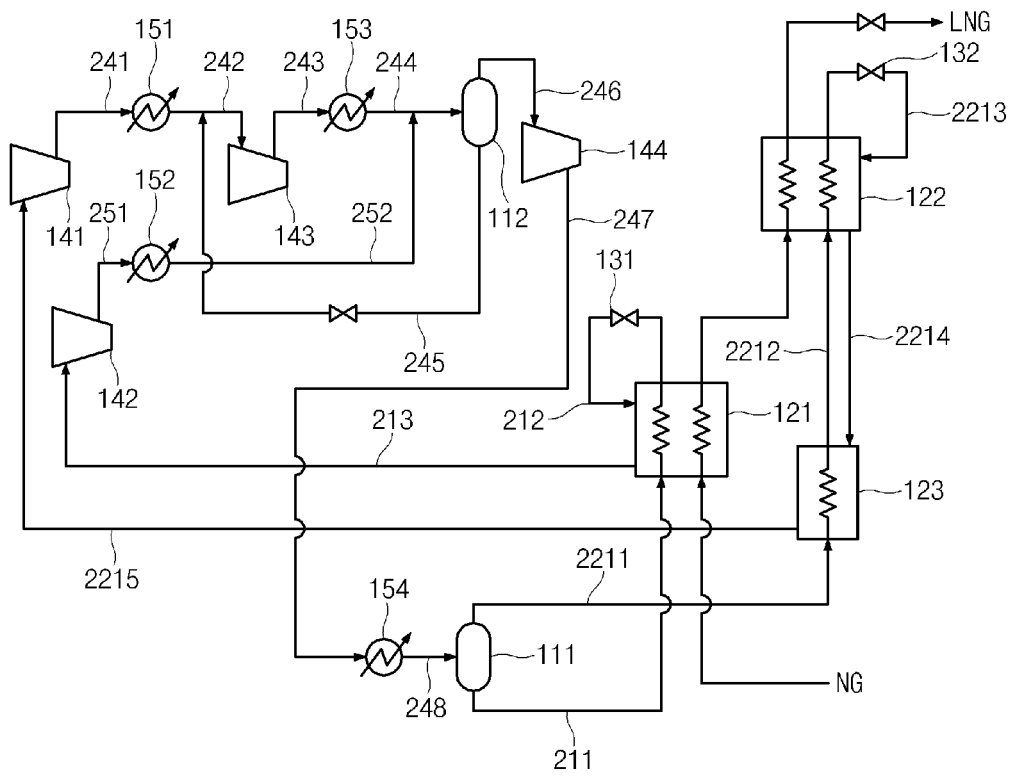
[Fig. 6]



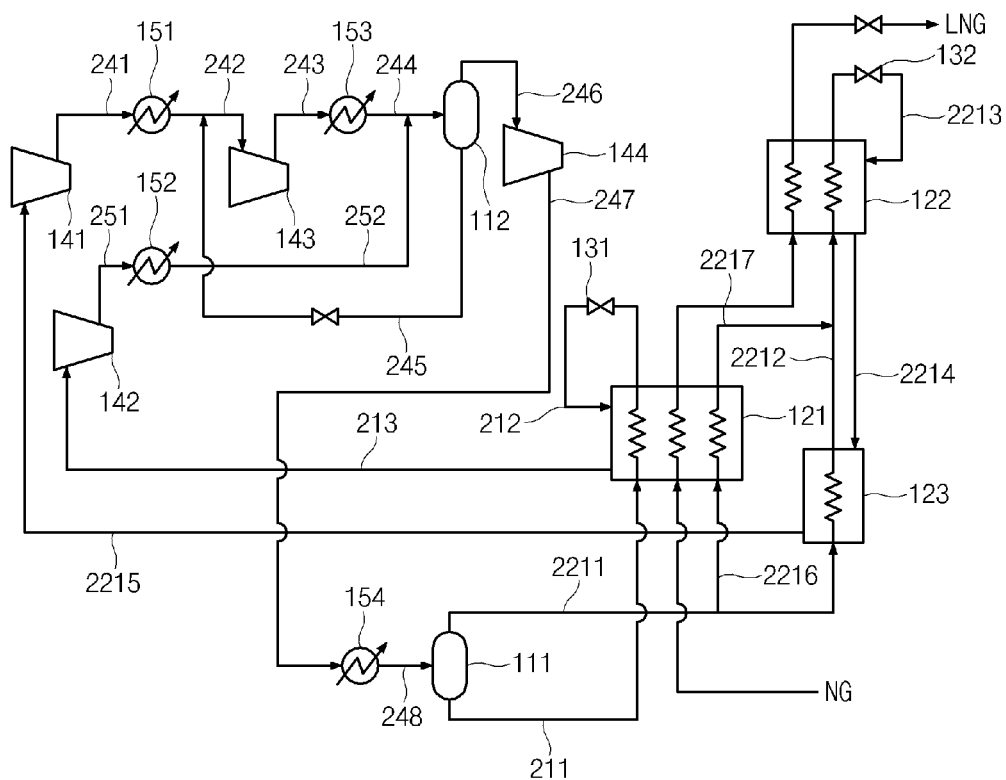
[Fig. 7]



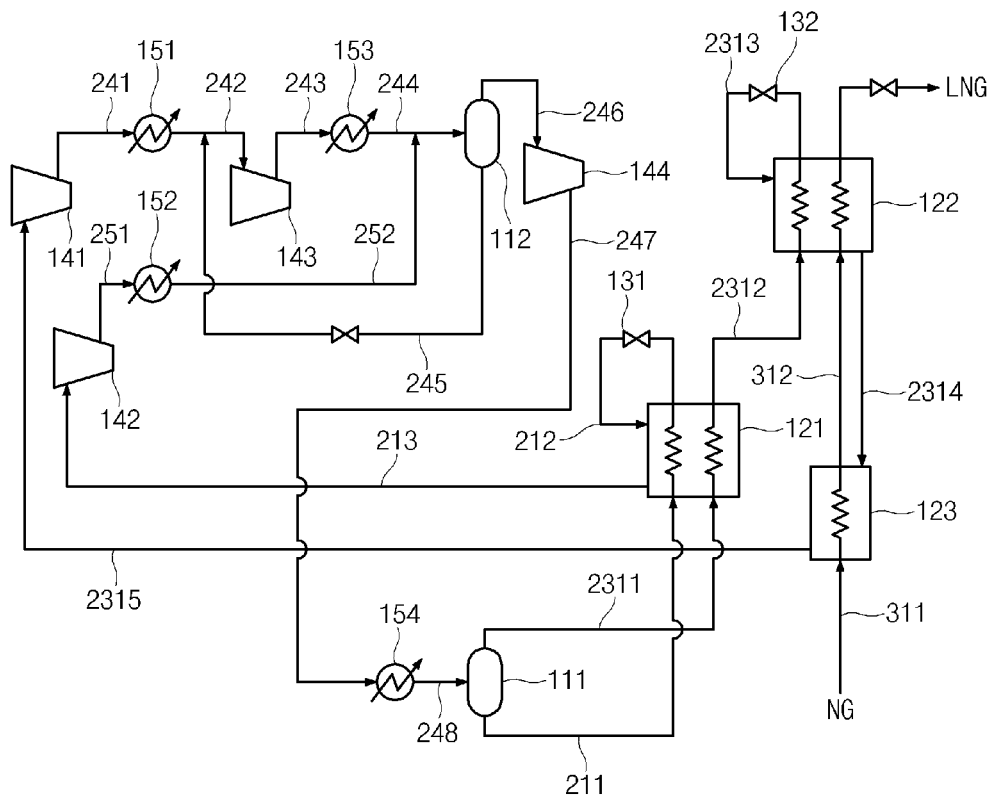
[Fig. 8]



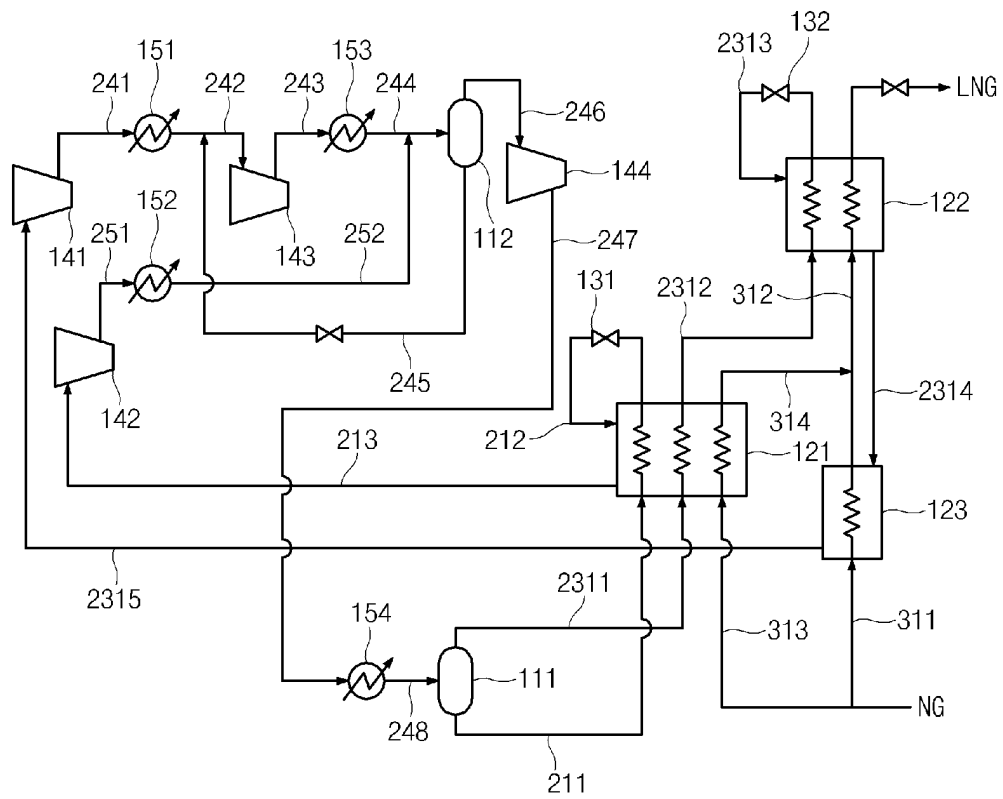
[Fig. 9]



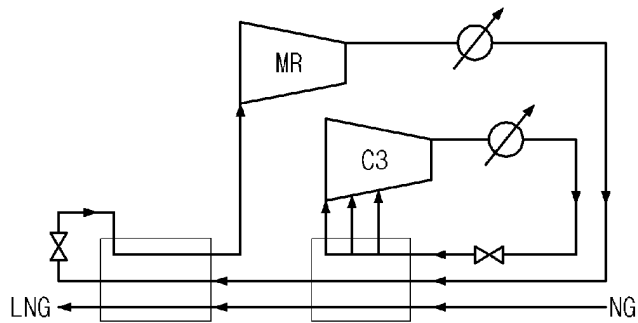
[Fig. 10]



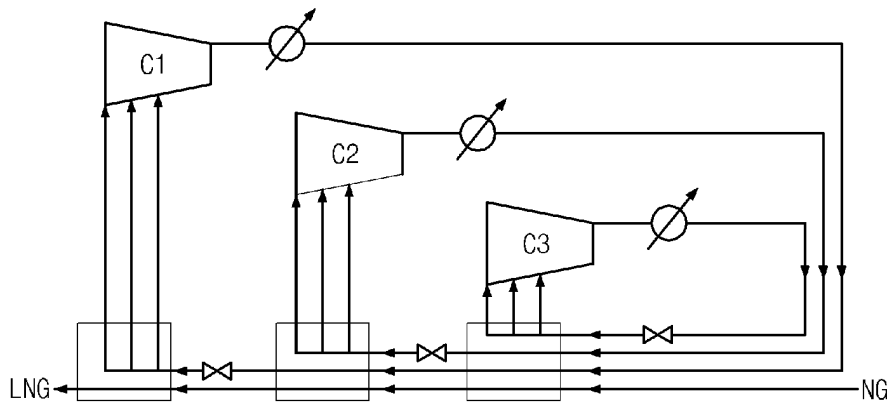
[Fig. 11]



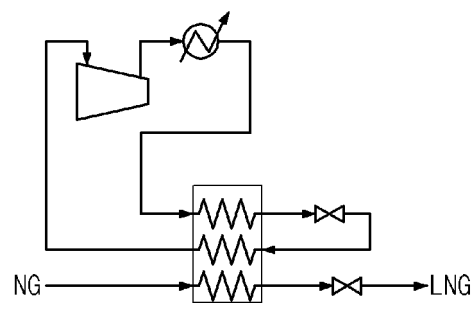
[Fig. 12]



[Fig. 13]



[Fig. 14]



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 6308531 B [0006]