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NATURAL GAS USING SINGLE MIXED
REFRIGERANT AS REFRIGERATION
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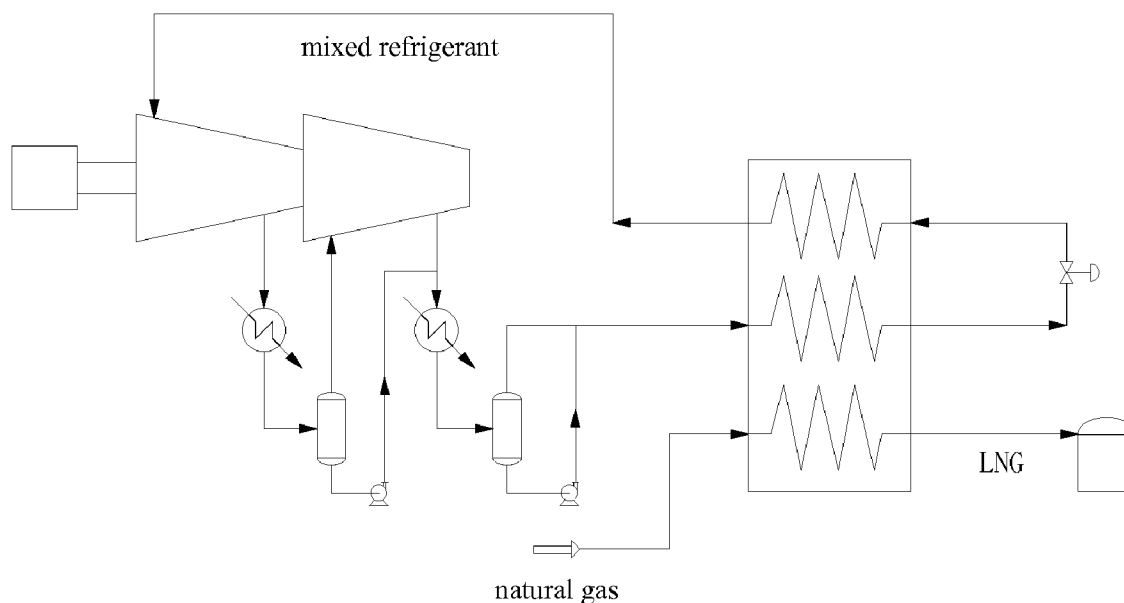
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(57) **ABSTRACT**

A system and a method for liquefying natural gas using single mixed refrigerant as refrigeration medium are provided. The system comprises a two-stage mixed refrigerant compressor (1) driven by a motor, two coolers (21, 22), a liquid pump (4), three gas-liquid separators (31, 32, and 6), two throttling devices (51, 52), a plate-fin heat exchanger group (7) and a LNG storage tank (8). The method comprises the following steps: the mixed refrigerant is compressed step by step by using the two-stage mixed refrigerant compressor (1), separated step by step, and gas-phase and liquid phase mixed refrigerant streams obtained from the separation flow into different passages of the heat exchanger group (7) respectively for throttling and heat exchanging. Heat exchange curves of cold fluid and hot fluid in the whole heat exchange process match with each other better by using two-stage heat exchange, thereby flow of the mixed refrigerant is reduced effectively.



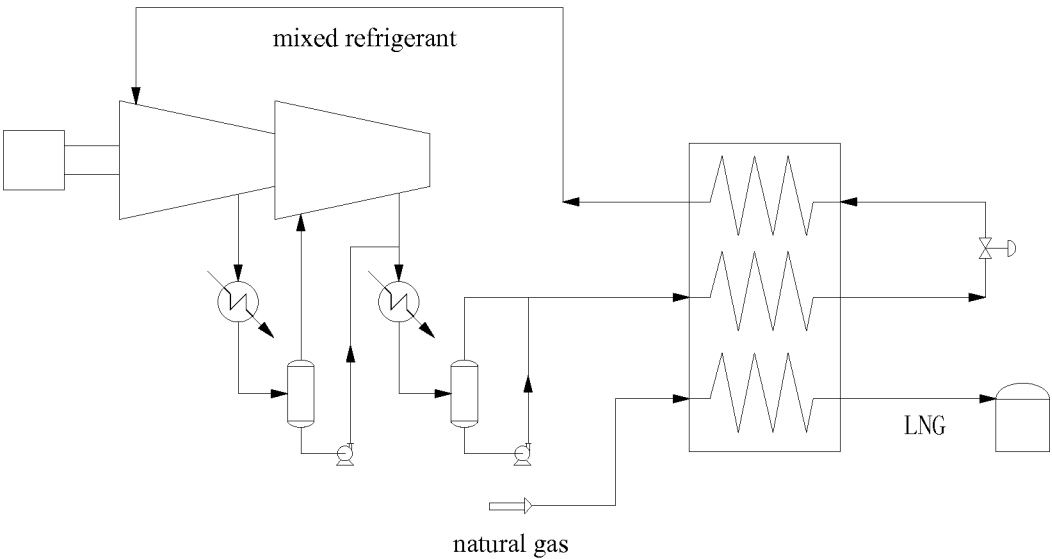


Figure 1

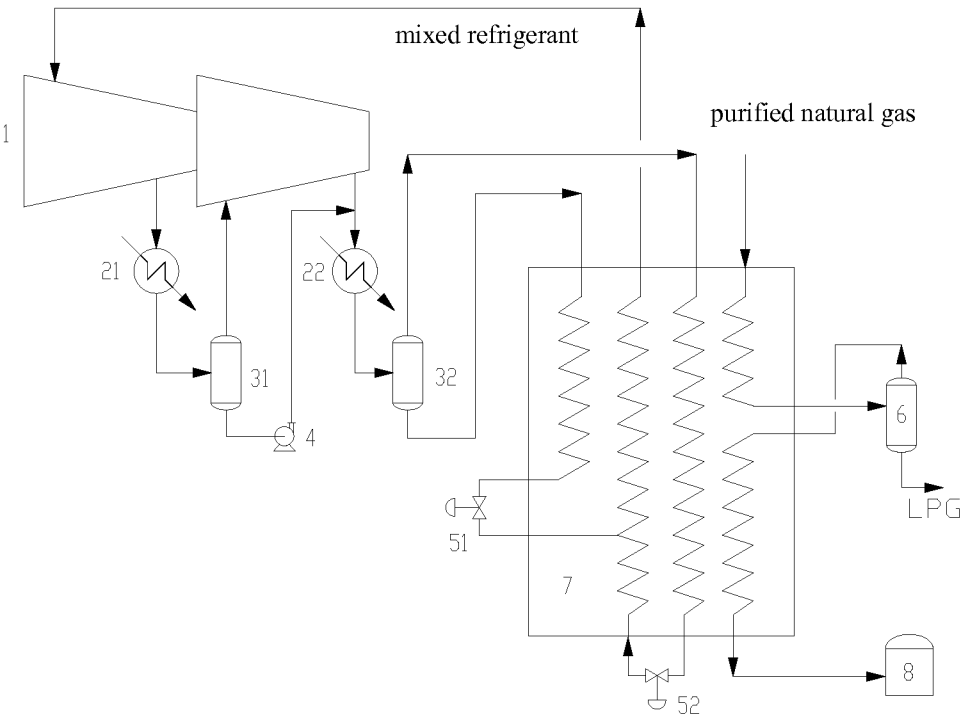


Figure 2

SYSTEM AND METHOD FOR LIQUEFYING NATURAL GAS USING SINGLE MIXED REFRIGERANT AS REFRIGERATION MEDIUM

FIELD OF THE INVENTION

[0001] The present invention relates to the liquefaction of a hydrocarbon-rich gas, and particularly to a system and a method for liquefying natural gas using single mixed refrigerant as refrigeration medium.

BACKGROUND OF THE INVENTION

[0002] Natural gas is becoming the best material to replace other fuels because of its environmental friendliness, and its fields of application has gradually expanded to power generation, automotive gas, industrial gas, domestic gas, chemical gas etc.

[0003] With the growth of natural gas consumption, the trade volume of liquefied natural gas as one of the most effective forms for supplying natural gas has become one of the fastest growth areas in the energy market. Continuous development of liquefied natural gas industry places stricter requirements for energy consumption, investment, efficiency etc. of the natural gas liquefaction method and apparatus.

[0004] Currently, the relatively well-established techniques for liquefying natural gas mainly comprise: cascade refrigeration technology, expansion refrigeration technology and mixed refrigerant refrigeration process. Among them, single mixed refrigerant refrigeration process is more preferable for medium-sized LNG plant.

[0005] In the existing process for liquefying natural gas by single mixed refrigerant refrigeration, the refrigerant compressor system comprises two compressor stages, and liquefaction of natural gas uses one-stage heat exchange.

[0006] In the prior art, as shown in FIG. 1, the system comprises a two-stage mixed refrigerant compressor driven by a motor, two coolers, two gas-liquid separators, two liquid pumps, a plate-fin heat exchanger and a LNG storage tank. The mixed refrigerant composed of C1~C5 alkanes and N₂ in a reasonable proportion is fed into the inlet of the compressor, compressed to 0.6~1 MPa by first stage compression, entered into the first stage cooler and cooled to 30~40° C., and then introduced into the first stage gas-liquid separator for gas-liquid separation. The gas separated from the top of the first stage gas-liquid separator is fed to the inlet of the second stage compressor, compressed to 1.6~2.5 MPa by the second stage compression; and the liquid obtained at the bottom of the first stage gas-liquid separator is pressurized by the first liquid pump, mixed with the gas from the outlet of the second stage compressor, further introduced to the second stage cooler and cooled to 30~40° C., and then the mixed refrigerant after cooling is fed to the second stage gas-liquid separator for gas-liquid separation. The separated liquid is pressurized by the second liquid pump and mixed with the gas obtained at the top of the second stage gas-liquid separator. The resulting mixture is fed to the plate-fin heat exchanger, precooled to the determined temperature, throttled after exiting from the heat exchanger, and returned to the plate-fin heat exchanger again for providing cold energy for the overall heat exchanging process. The natural gas is supplied to the LNG storage tank after passing through the plate-fin heat exchanger.

[0007] In the above-said process, to ensure that the liquid and the gas are fed to the same passage of the plate-fin heat

exchanger and participated in heat exchanging, the liquid obtained at the bottom of the final stage gas-liquid separator needs to be pressurized to overcome the liquid column pressure resulted from the height difference from the liquid outlet of the bottom of the gas-liquid separator to the refrigerant inlet of the top of the plate-fin heat exchanger, which is achieved by providing the final stage liquid pump. The heat exchange process between the refrigerant and natural gas in the plate-fin heat exchanger is the first stage heat exchange, the optimization of the temperature difference for heat exchange between the streams is limited to some extent, and the energy consumption of the apparatus is high. Further, there is no good adaptability to load-variable operation of the apparatus.

SUMMARY OF THE INVENTION

[0008] The present invention relates to a process for liquefying natural gas by using single mixed refrigerant as refrigeration medium.

[0009] The present invention provides a system for liquefying natural gas using single mixed refrigerant as refrigeration medium, comprising a mixed refrigerant compressor system and a cold box system (heat exchanger),

[0010] wherein:

[0011] the mixed refrigerant compressor system uses a two-stage mixed refrigerant compressor for compressing,

[0012] said compressor system comprises:

[0013] said two-stage mixed refrigerant compressor;

[0014] two coolers (i.e., the first cooler and the second cooler) respectively connected to the first stage and the second stage of the two-stage mixed refrigerant compressor;

[0015] a first gas-liquid separator and a second gas-liquid separator respectively connected to the first cooler and the second cooler; and

[0016] a liquid pump connected to the first stage gas-liquid separator,

[0017] the cold box system comprises:

[0018] a plate-fin heat exchanger group connected to the liquid phase port of the second gas-liquid separator;

[0019] two throttling devices connected to the heat exchange passages of the plate-fin heat exchanger group; and

[0020] a heavy hydrocarbon separator connected to a separate heat exchange passage of the plate-fin heat exchanger group,

[0021] the gas phase port of the first gas-liquid separator is connected to the second stage of the two-stage mixed refrigerant compressor,

[0022] the liquid phase discharge line of the first gas-liquid separator is converged via a liquid pump with the discharge line of the second compressor stage, and then connected to the second cooler,

[0023] the gas phase port and liquid phase port of the second gas-liquid separator are connected respectively to two heat exchange passages of the plate-fin heat exchanger group,

[0024] a natural gas line is connected to the heavy hydrocarbon separator via the above-mentioned separate heat exchange passage of the plate-fin heat exchanger group, and

[0025] the gas phase port at the top of the heavy hydrocarbon separator is connected to LNG storage tank after passing through a heat exchange passage of the plate-fin heat exchanger.

[0026] The system for liquefying natural gas using single mixed refrigerant as refrigeration medium in the present invention has a natural gas cycle and a mixed refrigerant refrigeration cycle. In the mixed refrigerant refrigeration cycle, the mixed refrigerant is compressed by two-stage compression, the stage-by-stage compression is accompanied by stage-by-stage gas-liquid separation, and the liquid phase stream separated from the first stage compression does not participate in the subsequent compression process, which effectively reduces the power consumption of the subsequent gas compression. The gas phase and liquid phase mixed refrigerant streams obtained by compression are fed respectively to different passages of the heat exchanger group for throttling and heat exchanging, the final stage liquid pump is omitted (i.e., only one liquid pump is used) compared to the existing process, and the heat exchange curves of cold fluid and hot fluid in the whole heat exchange process match with each other better by using two-stage heat exchange.

[0027] The system for liquefying natural gas using single mixed refrigerant as refrigeration medium in the present invention comprises a two-stage mixed refrigerant compressor, coolers, gas-liquid separators, throttling devices, a plate-fin heat exchanger group and a LNG storage tank. The mixed refrigerant compressor system comprises: a two-stage mixed refrigerant compressor, two coolers, two gas-liquid separators, and a liquid pump, and the cold box system comprises a plate-fin heat exchanger group (two-stage heat exchange), a heavy hydrocarbon separator (i.e., a gas-liquid separator) and two throttling devices. The overall heat exchange of the mixed refrigerant and natural gas is conducted in the cold box system.

[0028] In the mixed refrigerant compressor system, the outlet of the first stage compressor is connected to the first cooler, and the latter is connected to the first gas-liquid separator. The gas phase port of the first gas-liquid separator is connected to the second stage compressor, the liquid phase port at the bottom of the first gas-liquid separator is connected to a liquid pump, and the output line of the liquid pump is converged with the output line of the second stage compressor and then connected to the second cooler. The second cooler is then connected to the second gas-liquid separator. The gas phase port of the top of the second gas-liquid separator is connected to the first heat exchange passage (the gas phase passage) of the heat exchanger group, and the liquid phase port of the bottom of the second gas-liquid separator is connected to the second heat exchange passage of the heat exchanger group.

[0029] In the cold box system, the liquid phase port at the bottom of the second gas-liquid separator is in fluid communication with an end of the first throttling device via the second heat exchange passage of the heat exchanger group, and another end of the first throttling device is connected to the third heat exchange passage of the heat exchanger group. The gas phase port at the top of the second gas-liquid separator is connected to the first heat exchange passage (the gas phase passage) of the heat exchanger group for precooling, and then connected to an end of the second throttling device, and another end of the second throttling device is connected to the third heat exchange passage of the heat exchanger group and then connected to the first stage compressor. A natural gas line is connected to the fourth heat exchange

passage of the heat exchanger group and then to the heavy hydrocarbon separator. The gas phase port at the top the heavy hydrocarbon separator is in fluid communication with the LNG storage tank via subsequent stages of the heat exchanger (such as a fifth heat exchange passage).

[0030] More particularly, the present invention provides a system for liquefying natural gas using single mixed refrigerant as refrigeration medium, comprising a mixed refrigerant compressor system and a cold box system (heat exchanger),

[0031] wherein:

[0032] the mixed refrigerant compressor system comprises a two-stage mixed refrigerant compressor,

[0033] a first cooler and a second cooler respectively connected to the first stage and the second stage of the two-stage mixed refrigerant compressor;

[0034] a first gas-liquid separator and a second gas-liquid separator respectively connected to the first cooler and the second cooler; and

[0035] a liquid pump connected to the first gas-liquid separator,

[0036] and the cold box system comprises:

[0037] a plate-fin heat exchanger group comprising at least five heat exchange passages, i.e. the first, second, third, fourth and fifth heat exchange passages, the first and second heat exchange passages are connected to the gas phase port and the liquid phase port of the second gas-liquid separator, respectively, and the third heat exchange passage is connected to the first stage compressor;

[0038] a first throttling device connected to the second and third heat exchange passages of the plate-fin heat exchanger group;

[0039] a second throttling device connected to the first and third heat exchange passages of the plate-fin heat exchanger group; and

[0040] a heavy hydrocarbon separator connected to a separate heat exchange passage, i.e., the fourth heat exchange passage of the plate-fin heat exchanger group,

[0041] the gas phase port of the first gas-liquid separator is connected to the second stage of the two-stage mixed refrigerant compressor,

[0042] the liquid phase discharge line of the first gas-liquid separator is converged via a liquid pump with the discharge line of the second compressor stage, and then connected to the second cooler,

[0043] the gas phase port and liquid phase port of the second gas-liquid separator are connected to two heat exchange passages, i.e., the first and second heat exchange passages of the plate-fin heat exchanger group respectively,

[0044] a natural gas line is connected to the heavy hydrocarbon separator via the above-mentioned separate heat exchange passage, i.e., the fourth heat exchange passage of the plate-fin heat exchanger group, and

[0045] the gas phase port at the top of the heavy hydrocarbon separator is connected to the LNG storage tank after passing through a heat exchange passage, i.e., the fifth heat exchange passage of the plate-fin heat exchanger.

[0046] Alternatively, the gas phase port at the top of the heavy hydrocarbon separator is connected to the LNG storage tank after passing through the fifth and sixth heat exchange passages of the plate-fin heat exchanger successively.

[0047] The “first compressor stage” and “first stage compressor” as described herein can be used interchangeably, and so on.

[0048] The method for liquefying natural gas using single mixed refrigerant as refrigeration medium is described hereafter. In the mixed refrigerant compressor system, the gas exited from the first compressor stage in the mixed refrigerant compressor system is passed through the first cooler and cooled, and then entered into the first gas-liquid separator for gas-liquid separation; the gas phase after separation is passed through the second compressor stage, and the liquid phase after separation is pressurized by a liquid pump, converged with the hot gas obtained after the second stage compression, cooled by the second cooler, and introduced to the second gas-liquid separator for gas-liquid separation; and the gas phase obtained at the top of the second gas-liquid separator is passed through the first heat exchange passage (i.e. the gas phase passage) of the downstream heat exchanger, and the liquid phase obtained at the bottom of the second gas-liquid separator is passed through the second, liquid phase heat exchange passage of the downstream heat exchanger. In the cold box system, the liquid refrigerant from the bottom of the second gas-liquid separator in the mixed refrigerant compressor system is passed through the second, liquid phase heat exchange passage of the heat exchanger group, pre-cooled and then throttled by the first throttling device; the throttled stream is returned to the third heat exchange passage of the heat exchanger group for providing cold energy; the gas refrigerant from the top of the second gas-liquid separator is passed through the first heat exchange passage of the heat exchanger group, pre-cooled and then throttled by the second throttling device; the throttled gas stream is reversely passed through the third heat exchange passage of the heat exchanger group for providing cold energy. The mixed refrigerant exited from the third heat exchange passage is fed to the first stage compressor. Natural gas is firstly passed through the fourth heat exchange passage, cooled to a given temperature and then entered into the heavy hydrocarbon separator for separation. The heavy hydrocarbon component is obtained at the bottom of the heavy hydrocarbon separator. The gas phase component obtained at the top of heavy hydrocarbon separator is further passed through the other stages (such as the fifth heat exchange passage) of the heat exchanger group for heat exchanging, cooled to supercooled state, and thus obtained LNG is delivered to the LNG storage tank for storing.

[0049] The method for liquefying natural gas using single mixed refrigerant as refrigeration medium comprises:

[0050] A) natural gas cycle:

[0051] Purified natural gas as a raw material is firstly passed through the fourth heat exchange passage of a plate-fin heat exchanger group, cooled to $-30^{\circ}\text{C}.$ – $60^{\circ}\text{C}.$ and then entered into the heavy hydrocarbon separator for separation,

[0052] The gas phase component separated from the top of heavy hydrocarbon separator is further passed through the other stages (such as the fifth heat exchange passage) of the heat exchanger group for heat exchanging, cooled to $-130^{\circ}\text{C}.$ – $166^{\circ}\text{C}.$, and thus obtained LNG is delivered to the LNG storage tank for storing;

[0053] B) mixed refrigerant cycle:

[0054] The mixed refrigerant composed of C_1 – C_5 alkanes and N_2 (usually four or five or six components selected from C_1 , C_2 , C_3 , C_4 , C_5 alkanes and N_2 , and these components are mixed in any volume ratio or in substantially equal ratio) is fed into the inlet of the compressor, compressed to 0.6–1.8

MPa by first stage compression, entered into the first cooler and cooled to $30^{\circ}\text{C}.$ – $40^{\circ}\text{C}.$, and then introduced into the first gas-liquid separator for gas-liquid separation;

[0055] the gas separated from the top of the first gas-liquid separator is fed to the inlet of the second stage compressor, compressed to 1.2–5.4 MPa by the second stage compression;

[0056] the liquid separated from the liquid phase port at the bottom of the first gas-liquid separator is pressurized by the liquid pump, mixed with the hot gas from the outlet of the second stage compressor, further introduced to the second cooler and cooled to $30^{\circ}\text{C}.$ – $40^{\circ}\text{C}.$, and then the mixed refrigerant after cooling is fed to the second gas-liquid separator for gas-liquid separation;

[0057] the gas obtained at the top of the second gas-liquid separator is passed through the first heat exchange passage of the main heat exchanger group for heat exchanging, and the liquid separated from the bottom of the second gas-liquid separator is passed through the second heat exchange passage of the main heat exchanger group for heat exchanging;

[0058] the liquid separated from the bottom of the second gas-liquid separator is pre-cooled to about $-30^{\circ}\text{C}.$ – $80^{\circ}\text{C}.$ in the second heat exchange passage of the heat exchanger group, throttled to 0.25–0.75 MPaA by the first throttling device, converged with the mixed refrigerant stream, which is passed through the first heat exchange passage of the main heat exchanger group and returned via the second throttling device (into the third heat exchange passage), and reversely entered into the third heat exchange passage for providing cold energy for the heat exchanger group and then returned to the first compressor stage;

[0059] the gas stream of the mixed refrigerant separated from the top of the second gas-liquid separator is cooled to $-135^{\circ}\text{C}.$ – $169^{\circ}\text{C}.$ in the gas phase passage (the first heat exchange passage) of the heat exchanger group, throttled to 0.25–0.75 MPaA by the second throttling device, and reversely entered into the third heat exchange passage for providing cold energy for the heat exchanger group.

[0060] The pressure unit “MPaA” as described herein refers to Megapascal, absolute pressure. In the present invention, connection of one device to another device is achieved through a pipeline.

[0061] The advantages of the present invention are as follows:

[0062] 1. The system of the present invention uses a two-stage mixed refrigerant compressor, compresses and separates the mixed refrigerant stage by stage, which reduces the power consumption for gas compression.

[0063] 2. The liquid stream obtained at the bottom of the first gas-liquid separator does not participate in the subsequent stream compression process, which to some extent reduces the influence of the fluctuation of the mixed refrigerant ratio on the compressor running conditions, making the system easier to operate.

[0064] 3. The gas phase and liquid phase mixed refrigerant streams obtained by compression using the mixed refrigerant compressor are fed to different passages of the heat exchanger group, and the final stage liquid pump is omitted (i.e., only one liquid pump is used), which may decrease the energy consumption. Furthermore, the heat exchange curves of cold fluid and hot fluid in the total heat exchange process match with each other better by the aid of using two-stage heat exchange, which can reduce the flow of the mixed refrigerant.

[0065] 4. The system of the present invention has a good adaptability to load-variable operation of the apparatus, which can effectively avoid abnormal liquid-flooding at the bottom of the cold box, thus ensuring energy consumption under low load conditions, is close to energy consumption at normal operating conditions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0066] FIG. 1 shows a system for liquefying natural gas in the prior art.

[0067] FIG. 2 shows the system for liquefying natural gas using two-stage mixed refrigerant compressor system in the present invention.

THE MODE OF CARRYING OUT THE INVENTION

[0068] The embodiments of the present invention are further described with reference to the Drawings.

[0069] The mixed refrigerant compressor system as shown in FIG. 2 comprises a two-stage mixed refrigerant compressor 1, a first cooler 21, a second cooler 22, a first gas-liquid separator 31, a second gas-liquid separator 32, a heavy hydrocarbon separator 6 (gas-liquid separator), a liquid pump 4, a first throttling device 51, a second throttling device 52, a plate-fin heat exchanger group 7 (i.e. the main heat exchanger group) and a LNG storage tank 8. Its mixed refrigerant compressor system comprises the two-stage mixed refrigerant compressor 1, two cooler 21 and 22, two gas-liquid separator 31 and 32, one liquid pump 4, and the cold box system comprises the plate-fin heat exchanger group 7 (two-stage heat exchange), the heavy hydrocarbon separator 6 (i.e., a gas-liquid separator) and two throttling devices 51 and 52. Heat exchange of the mixed refrigerant and natural gas is conducted in the cold box system.

[0070] In the mixed refrigerant compressor system, the outlet of the first stage of the compressor 1 is connected to the first cooler 21, and the latter is connected to the first gas-liquid separator 31. The gas phase port of the first gas-liquid separator 31 is connected to the second stage compressor, the liquid phase port at the bottom of the first gas-liquid separator 31 is connected to the liquid pump 4, and the output line of the liquid pump 4 is converged with the output line of the second stage compressor and then connected to the second cooler 22. The second cooler 22 is then connected to the second gas-liquid separator 32. The gas phase port at the top of the second gas-liquid separator 32 is in fluid communication with the first heat exchange passage (the gas phase passage) of the heat exchanger group 7, and the liquid phase port at the bottom of the second gas-liquid separator 32 is in fluid communication with the second heat exchange passage of the heat exchanger group 7.

[0071] In the cold box system, the liquid phase port at the bottom of the second gas-liquid separator 32 is passed through the second heat exchange passage of the heat exchanger group 7 and then connected to one end of the first throttling device 51, and another end of the first throttling device 51 is connected to the third heat exchange passage of the heat exchanger group 7. The gas phase port at the top of the second gas-liquid separator 32 is connected to the first heat exchange passage (the gas phase passage) of the heat exchanger group 7 for precooling, and then connected to one end of the second throttling device 52, and another end of the second throttling device 52 is connected to the third heat

exchange passage of the heat exchanger group 7 and then connected to the first stage compressor. A natural gas line passes through the fourth heat exchange passage of the heat exchanger group and then is connected to the heavy hydrocarbon separator 6. The gas phase port at the top of the heavy hydrocarbon separator 6 passes through subsequent stages (such as a fifth heat exchange passage) of the heat exchanger and then is connected to the LNG storage tank 8.

[0072] The method for liquefying natural gas using the system as shown in FIG. 2 comprises:

[0073] A) natural gas cycle:

[0074] Purified natural gas as a raw material is firstly passed through the fourth heat exchange passage of the plate-fin heat exchanger group 7 (two-stage heat exchange), cooled to $-30^{\circ}\text{C.}\sim 60^{\circ}\text{C.}$ and then entered to the heavy hydrocarbon separator 6 for gas-liquid separation,

[0075] The gas phase component separated from the top of heavy hydrocarbon separator 6 is further passed through the other stages (such as the fifth heat exchange passage) of the heat exchanger group 7 for heat exchanging, cooled to $-130^{\circ}\text{C.}\sim 166^{\circ}\text{C.}$, and thus obtained Liquefied natural gas (LNG) is delivered to the LNG storage tank 8 for storing. Liquefied petroleum gas (LPG) is obtained at the bottom of the heavy hydrocarbon separator 6.

[0076] B) mixed refrigerant cycle:

[0077] The mixed refrigerant composed of C1~C5 alkanes and N_2 (usually four or five or six components selected from C1, C2, C3, C4, C5 alkanes and N_2 , and these components are mixed in any volume ratio or in substantially equal ratio) is fed into the inlet of the compressor 1, compressed to 0.6~1.8 MPa by first stage compression, entered into the first stage cooler 21 and cooled to $30^{\circ}\text{C.}\sim 40^{\circ}\text{C.}$, and then introduced into the first stage gas-liquid separator 31 for gas-liquid separation;

[0078] the gas separated from the top of the first stage gas-liquid separator 31 is fed to the inlet of the second stage compressor, compressed to 1.2~5.4 MPa by the second stage compression;

[0079] the liquid separated from the liquid phase port at the bottom of the first stage gas-liquid separator 31 is pressurized by the liquid pump 4, mixed with the hot gas from the outlet of the second stage compressor, further introduced to the second cooler 22 and cooled to $30^{\circ}\text{C.}\sim 40^{\circ}\text{C.}$, and then the mixed refrigerant after cooling is fed to the second stage gas-liquid separator 32 for gas-liquid separation;

[0080] the gas obtained at the top of the second stage gas-liquid separator 32 is passed through the first heat exchange passage of the main heat exchanger group 7 for heat exchanging, and the liquid separated from the bottom of the second stage gas-liquid separator 32 is passed through the second heat exchange passage of the main heat exchanger group 7 for heat exchanging;

[0081] the liquid separated from the bottom of the second stage gas-liquid separator 32 is pre-cooled to about $-30^{\circ}\text{C.}\sim 80^{\circ}\text{C.}$ in the second heat exchange passage of the heat exchanger group, throttled to 0.25~0.75 MPaA by the first throttling device 51, converged with the mixed refrigerant stream returned from the latter stage of the heat exchanger group 7 (i.e., via the first heat exchange passage and the second throttling device), and reversely entered into the former stage heat exchanger (i.e., the third heat exchange passage) for providing cold energy for the heat exchanger group 7 and then returned to the first compressor stage;

[0082] the gas stream of the mixed refrigerant separated from the top of the second stage gas-liquid separator 32 is cooled to $-135^{\circ}\text{C}.$ ~ $-169^{\circ}\text{C}.$ in the gas phase passage (the first heat exchange passage) of the heat exchanger group 7, throttled to 0.25~0.75 MPaA by the second throttling device 52, reversely entered into the third heat exchange passage for providing cold energy for the heat exchanger group, and then returned to the first stage compressor.

1. A system for liquefying natural gas using single mixed refrigerant as refrigeration medium, the system comprising a mixed refrigerant compressor system and a cold box system, wherein:

the mixed refrigerant compressor system comprises a two-stage mixed refrigerant compressor;

a first cooler and a second cooler respectively connected to a first stage and a second stage of the two-stage mixed refrigerant compressor;

a first gas-liquid separator and a second gas-liquid separator respectively connected to the first cooler and the second cooler; and

a liquid pump connected to the first gas-liquid separator, and the cold box system comprises:

a plate-fin heat exchanger group comprising at least five heat exchange passages including a first, second, third, fourth and fifth heat exchange passages, the first and second heat exchange passages are connected to a gas phase port and a liquid phase port of the second gas-liquid separator, respectively, and the third heat exchange passages is connected to the first stage of the two-stage mixed refrigerant compressor;

a first throttling device connected to the second and third heat exchange passages of the plate-fin heat exchanger group;

a second throttling device connected to the first and third heat exchange passages of the plate-fin heat exchanger group; and

a heavy hydrocarbon separator connected to the fourth heat exchange passage of the plate-fin heat exchanger group, the gas phase port of the first gas-liquid separator is connected to the second stage of the two-stage mixed refrigerant compressor,

a liquid phase discharge line of the first gas-liquid separator is converged via the liquid pump with the discharge line of the second stage of the two-stage mixed refrigerant compressor, and then connected to the second cooler,

a gas phase port and a liquid phase port of the second gas-liquid separator are connected to the first and second heat exchange passages of the plate-fin heat exchanger group respectively,

a natural gas line is connected to the heavy hydrocarbon separator via the fourth heat exchange passage of the plate-fin heat exchanger group, and

a gas phase port at a top of the heavy hydrocarbon separator is connected to an LNG storage tank after passing through the fifth heat exchange passage of the plate-fin heat exchanger.

2. The system according to claim 1, characterized in that the gas phase port at the top of the heavy hydrocarbon separator is connected to the LNG storage tank after passing through the fifth and a sixth heat exchange passages of the plate-fin heat exchanger successively.

3. A method for liquefying natural gas using single mixed refrigerant as refrigeration medium, the method comprising:

passing purified natural gas as a raw material firstly through a fourth heat exchange passage of a plate-fin heat exchanger group, cooled to $-30^{\circ}\text{C}.$ ~ $-60^{\circ}\text{C}.$ and then entering the natural gas into a heavy hydrocarbon separator for gas-liquid separation,

passing a gas phase component separated from a top of heavy hydrocarbon separator further through a fifth heat exchange passage of the plate-fin heat exchanger group for heat exchanging, cooled to $-130^{\circ}\text{C}.$ ~ $-166^{\circ}\text{C}.$, and thus obtaining LNG and delivering the LNG to an LNG storage tank for storing;

feeding a mixed refrigerant composed of C1~C5 alkanes and N_2 into an inlet of a compressor, compressed to 0.6~1.8 MPa by first stage compression, entering into a first cooler and cooling to $30^{\circ}\text{C}.$ ~ $40^{\circ}\text{C}.$, and then introducing into a first gas-liquid separator for gas-liquid separation;

feeding gas separated from a top of the first gas-liquid separator to an inlet of a second stage compressor, compressed to 1.2~5.4 MPa by second stage compression;

pressurizing liquid separated from a liquid phase port at a bottom of the first stage gas-liquid separator by a liquid pump, mixing with hot gas from an outlet of the second stage compressor, further introducing to a second cooler and cooling to $30^{\circ}\text{C}.$ ~ $40^{\circ}\text{C}.$, and then feeding the mixed refrigerant after cooling to a second gas-liquid separator for gas-liquid separation;

passing gas obtained at a top of the second gas-liquid separator through a first heat exchange passage of the plate-fin heat exchanger group for heat exchanging, and passing liquid separated from a bottom of the second gas-liquid separator through the second heat exchange passage of the plate-fin heat exchanger group for heat exchanging;

precooling liquid separated from the bottom of the second gas-liquid separator to about $-30^{\circ}\text{C}.$ ~ $-80^{\circ}\text{C}.$ in a second heat exchange passage of the plate-fin heat exchanger group, throttling to 0.25~0.75 MPaA by the first throttling device, converging with a mixed refrigerant stream which is passed through the first heat exchange passage of the plate-fin heat exchanger group and returned via the second throttling device, and entering reversely into a third heat exchange passage for providing cold energy for the heat exchanger group and then returning to a first compressor stage;

cooling a gas stream of mixed refrigerant separated from a top of the second gas-liquid separator to $-135^{\circ}\text{C}.$ ~ $-169^{\circ}\text{C}.$ in the first heat exchange passage of the plate-fin heat exchanger group, throttling to 0.25~0.75 MPaA by a second throttling device, and entering reversely into a third heat exchange passage for providing cold energy for the plate-fin heat exchanger group.

4. The method according to claim 3, characterized in that the mixed refrigerant comprises four or five or six components selected from C1, C2, C3, C4, C5 alkanes and N_2 , and these components are mixed in any volume ratio or in substantially equal ratio.

5. The method according to claim 3, characterized in that the gas phase port at the top of the heavy hydrocarbon separator is connected to the LNG storage tank after passing through the fifth and a sixth heat exchange passages of the plate-fin heat exchanger successively.

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