POWER MATCHED MIXED REFRIGERANT COMPRESSION CIRCUIT

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ABSTRACT

A refrigerant compressor circuit for use in a liquefaction plant includes a first compression string driven by a first driver; a second compression string driven by a second driver, a pre-cooling refrigerant compression stage arranged in the first compression string to receive a stream of pre-cooling refrigerant at an inlet pressure and discharge the pre-cooling refrigerant at an outlet pressure; a first compression stage arranged in the first compression string to compress a mixed refrigerant gas from a first pressure to a second pressure, and, a second compression stage arranged in the second compression string to compress the mixed refrigerant gas from the second pressure to a third pressure. The pre-cooling refrigerant compression stage and the first compression stage of the circuit are co-axially mounted on a first shaft drivingly coupled to a first driver in the first compression string.
POWER MATCHED MIXED REFRIGERANT COMPRESSION CIRCUIT

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of PCT/AU2009/001477, filed on Nov. 13, 2009, which claims priority from Australian Patent Application No. AU 2008905954, filed on Nov. 17, 2008, the disclosures of which are incorporated herein by reference in their entireties.

TECHNICAL FIELD

[0002] The present invention is directed to a refrigerant compression circuit for use in the liquefaction of natural gas or other methane-rich gas streams.

BACKGROUND

[0003] The cryogenic liquefaction of natural gas is routinely practiced as a means of converting natural gas into a more convenient form for transportation and storage. Liquefaction of large volumes of gas using a refrigerant circuit is energy and capital intensive. Broadly speaking, a plant for liquefying natural gas comprises a main heat exchanger in which a hydrocarbon gas feed stream is liquefied by means of indirect heat exchange with evaporating refrigerant in one or more stages. The plant further comprises a refrigerant circuit in which evaporated refrigerant(s) are compressed, cooled and returned to the main heat exchanger. The refrigerant circuit typically includes a compressor train consisting of at least one compressor body driven by means of a mechanical driver (e.g., a gas turbine, a steam turbine, or an electric motor) that is connected to the shaft of the compressor body via a common shaft or via a gearbox. The configuration of compressors and mechanical drivers in a gas processing plant greatly influences the energy efficiency of the plant.

[0004] An important criterion for a refrigerant circuit to be cost effective is to make full use of the installed power of each mechanical driver. There exists a continuing need in the gas processing field to provide alternative plants and methods to improve the power balance between the refrigerant compressors mounted on each shaft and the mechanical drivers powering each shaft.

SUMMARY

[0005] According to one aspect of the present invention, there is provided a refrigerant compressor circuit for use in a liquefaction plant, the refrigerant compressor circuit comprising:

[0006] a first compression string driven by a first driver;
[0007] a second compression string driven by a second driver;
[0008] a pre-cooling refrigerant compression stage arranged in the first compression string for receiving a stream of pre-cooling refrigerant at an inlet pressure and discharging the pre-cooling refrigerant at an outlet pressure;
[0009] a first compression stage arranged in the first compression string for compressing a mixed refrigerant gas from a first pressure to a second pressure; and,
[0010] a second compression stage arranged in the second compression string for compressing the mixed refrigerant gas from the second pressure to a third pressure;

[0011] wherein the pre-cooling refrigerant compression stage and the first compression stage are co-axially mounted on a first shaft drivingly coupled to a first driver in the first compression string.

[0012] In one form, a first intercooling heat exchanger may be arranged between the first compression stage and the second compression stage for removing heat of compression from the mixed refrigerant gas.

[0013] Alternatively or additionally, the mass flow of refrigerant to the second compression stage may be directed to flow through a first segment and then a second segment within a single back-to-back compressor body.

[0014] In one form, the first driver has more power than the second driver.

[0015] Alternatively or additionally, the first compression stage may be provided with a single compressor body having:

[0016] a first suction inlet arranged to receive a first stream of refrigerant and direct the flow of the first stream of refrigerant into a first segment; and
[0017] a second suction inlet arranged to receive a second stream of refrigerant and direct the flow of the second stream of refrigerant into a second segment;

[0018] wherein the first and second segments are arranged end to end such that the first and second suction inlets are arranged at distal ends of the single compressor body (50); and,

[0019] wherein the first and second streams are combined together as they flow out of a common outlet of the single compressor body.

[0020] In one form, the refrigerant circuit further comprises a first distribution means for splitting the mass flow of refrigerant gas to the first compression stage into the first stream and second stream such that the first stream fed to the first suction inlet and the second stream fed to the section suction inlet are symmetrical. In one form, the first distribution means may cause the mass flow of refrigerant to enter a branched tee such that half of the mass flow of refrigerant leaves the branched tee through one end of a straight run of pipe, whilst the other half of the mass flow of refrigerant leaves the branched tee in the opposite direction through the opposite end of the straight run of pipe.

[0021] In one form, the pre-cooling refrigerant compression stage comprises a single pre-cooling refrigerant compressor body with a plurality of suction inlets arranged to receive evaporated pre-cooling refrigerant at a corresponding plurality of different pressures.

[0022] Alternatively or additionally, the refrigerant circuit further comprises a third compression stage for compressing the mixed refrigerant gas from the third pressure to a fourth pressure. In this form, the second compression stage and the third compression stage may be co-axially mounted on a second shaft drivingly coupled to a second driver in the second compression string. Alternatively or additionally, the refrigerant circuit further comprises a second intercooling heat exchanger arranged between the second compression stage and the third compression stage for removing heat of compression from the refrigerant. In one form, the second and third compression stages may be combined within a single back to back compressor body.

[0023] According to a second aspect of the present invention, there is provided a plant for the production of a liquefied hydrocarbon product such as liquefied natural gas, the plant comprising:
[0024] A main heat exchanger in which natural gas is liquefied by means of indirect heat exchange with an evaporating mixed refrigerant; and,

[0025] A refrigerant circuit according to the first aspect of the present invention for compressing the evaporated refrigerant for re-use in the main heat exchanger system.

[0026] According to a third aspect of the present invention, there is provided a method for cooling, preferably liquefying, a hydrocarbon stream, wherein the hydrocarbon stream to be cooled by indirect heat exchange with an evaporating refrigerant, and the evaporated refrigerant is cooled using a refrigerant circuit according to the first aspect of the present invention.

[0027] According to a fourth aspect of the present invention, there is provided a refrigerant circuit substantially as herein described with reference to and as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] In order to facilitate a more detailed understanding of the nature of the invention embodiments will now be described in detail, by way of example only, with reference to the accompanying drawings, in which:

[0029] Fig. 1 is a schematic flowchart of a refrigerant compressor circuit using three mixed refrigerant compression stages and a pre-cooling refrigerant stage, with the first compression stage and the pre-cooling refrigerant stage arranged on a first compression string and the second and third compression stages arranged on a second compression string;

[0030] Fig. 2 is a schematic flowchart of an alternative embodiment of the refrigerant compressor circuit of Fig. 1 showing intercooling between each mixed refrigerant compression stage;

[0031] Fig. 3 is a schematic flowchart of an alternative embodiment of the refrigerant compressor circuit of Fig. 2 in which the second and third compression stages are provided in a single back-to-back compressor body;

[0032] Fig. 4 is a schematic flowchart of an alternative embodiment of the refrigerant compressor circuit of Fig. 3 showing intercooling between only the second and third mixed refrigerant compression stages;

[0033] Fig. 5 is a schematic flowchart of a refrigerant compressor circuit with two mixed refrigerant compressor stages, with the first compression stage and the pre-cooling refrigerant stage arranged on a first compression string and the second high pressure compression stage arranged on a second compression string;

[0034] Fig. 6 is a schematic flowchart of an alternative embodiment of the refrigerant compressor circuit of Fig. 5 in which the second high pressure compression stage is performed by the first and second segments of a single back-to-back compressor body;

[0035] Fig. 7 is a schematic flowchart of a refrigerant compressor circuit using three mixed refrigerant compression stages and a pre-cooling refrigerant stage, with the first compression stage and the pre-cooling refrigerant stage arranged on a first compression string and the second and third compression stages arranged on a second compression string, with the mass flow of refrigerant to the first compression stage being split across two separate suction inlets in a single compressor body;

[0036] Fig. 8 is a schematic flowchart of an alternative embodiment of the refrigerant compressor circuit of Fig. 7 with the second and third compression stages being provided in a single back-to-back compressor body;

[0037] Fig. 9 is a schematic flowchart of an alternative embodiment of the refrigerant compressor circuit of Fig. 7 without intercooling between the first and second compression stages;

[0038] Fig. 10 is a schematic flowchart of an alternative embodiment of the refrigerant compressor circuit of Fig. 9 with the second and third compression stages being provided in a single back-to-back compressor body.

DETAILED DESCRIPTION

[0039] The present invention will now be described in greater detail with reference to the accompanying drawings wherein several preferred embodiments of the present invention are set forth. Those skilled in the art will recognized that the accompanying drawings are schematic representations only and therefore, many items of equipment that would be needed in a commercial plant for successful operation have been omitted for the sake of clarity. Such items might include, for example, compressor controls, flow, level, temperature and pressure controls, pumps, motors, filters, additional heat exchangers, and valves, etc. It will be readily appreciated that a person skilled in the art would be able to include such items in accordance with standard engineering practice.

[0040] The term “compressor” as used herein refers to a device used to increase the pressure of an incoming fluid by decreasing its volume.

[0041] The term “compressor body” as used herein refers to a casing which holds the pressure side of the fluid passing through a compressor. While the compressors bodies used for the LPMR stage may be centrifugal (radial) type or axial, it is preferably to use centrifugal (radial) compressor bodies for the MPMR and HPMR compression stages.

[0042] The term “compression string” is used to describe one or more compressor bodies mounted on a common shaft and driven by a common driver.

[0043] The term “driver” as used herein refers to a mechanical device such as a gas turbine, a steam turbine, an electric motor or a combination thereof which is used to cause rotation of a shaft upon which a compression string is mounted.

[0044] The term “stage” as used herein means a compressor or compressor segment having one or more impellers wherein the mass flow of the fluid being compressed in the stage is constant through the stage. For mixed refrigerant compression, each stage is optionally defined by intercooling between them.

[0045] The term “intercooling” is used to refer to a process by which heat of compression is removed from a fluid between stages.

[0046] The term “back-to-back compressor” refers to a compressor body having two compression sections within a single casing, each stage having one inlet and one outlet.

[0047] As used herein, the terms “upstream” and “downstream” shall be used to describe the relative positions of various components of a natural gas liquefaction plant along the flow path of natural gas through the plant.

[0048] Preferred embodiments of the present invention are ideally suited to LNG trains with a capacity in the range of 4.5-6.5 million tonnes per annum (“mtpa”), but can be modified to suit processing plants of other capacities.

[0049] Numerous systems exist in the prior art for the liquefaction of a hydrocarbon feed stream by heat exchange with
one or more refrigerants such as propane, propylene, ethane, ethylene, methane, nitrogen or combinations of the preceding refrigerants (so-called “mixed refrigerant” systems). For example, U.S. Pat. No. 4,698,080 discloses a liquefaction plant of the so-called cascade type having three refrigeration circuits operating with different refrigerants, propane, ethylene and methane. An alternative to the cascade-type liquefaction plant is a so-called propylene-pre-cooled multi-component or “mixed refrigerant” (MR) liquefaction plant. Examples of liquefaction processes using mixed refrigerants are given in U.S. Pat. No. 5,832,745, U.S. Pat. No. 6,389,844, U.S. Pat. No. 6,370,910 and U.S. Pat. No. 7,219,512 (the contents of which are hereby specifically incorporated by reference). As methods and systems for liquefying a hydrocarbon stream are well known in the art they do not form a portion of the present invention and thus the operating conditions of the refrigeration side and the compositions of the refrigerants are not discussed in detail here.

Reference is now made to FIG. 1 in which a refrigerant compressor circuit (10) is illustrated using three stages of mixed refrigerant compression and a pre-cooling refrigerant compressions stages arranged on two compression strings. In this embodiment, the refrigerant compressor circuit (10) comprises a first low pressure (LPMR) compression stage (12) for compressing a mixed refrigerant gas from a first pressure to a second pressure, a second medium pressure (MPMR) compression stage (14) for compressing the mixed refrigerant gas for the second pressure to a third pressure, a third high pressure (HPMR) compression stage (16) for compressing the mixed refrigerant gas from the third pressure to a fourth pressure. The circuit (10) further comprises a pre-cooling refrigerant compression stage (18). The refrigerant circuit of the present invention differs from prior art refrigerant circuits in that both the pre-cooling refrigerant compression stage (18) and the first compression stage (12) are coaxially mounted on a first shaft (20) drivingly coupled to a first driver (22) in a first compression string (24). In the embodiment illustrated in FIG. 1, the second compression stage (14) and the third compression stage (16) are co-axially mounted on a second shaft (26) drivingly coupled to a second driver (28) in a second compression string (30). This arrangement is used to provide a more even power balance across each of the first and second compression strings (24 and 30, respectively) and improved efficiency over prior art refrigerant circuits where the pre-cooling refrigerant compressor driver has a lower power rating than the mixed refrigerant compressor driver.

Therefore, using the refrigerant compression circuit of the present invention, the power absorbed by the compressor bodies on each compression string is matched closely to the available driver power on that string. Where two drivers are being used, the absorbed power of the compressor bodies mounted on each shaft should be in same proportion as the available power from each driver. In cases where the available power is equal the target is to have a 50%-50% split between the compressor bodies on each shaft. This principle is independent of any capacity limitations.

The pre-cooling refrigerant compression stage (18) may comprise pre-cooling refrigerant evaporated by the cooling of the mixed refrigerant. Alternatively or additionally, it may be used to compress pre-cooling refrigerant evaporated in one or more pre-cooling heat exchangers used for the purpose of pre-cooling the hydrocarbon feed stream before it enters the main heat exchanger system, or for other purposes such as the fractionation of NGLs removed from the natural gas. Thus, the refrigerant being compressed using the pre-cooling refrigerant compressor body could be a substantially pure refrigerant such as propane or ammonia, or alternatively a separate mixed refrigerant with a different composition to the mixed refrigerant evaporated in the main heat exchanger system.

At least a portion of the cooling of the mixed refrigerant upstream of the main heat exchanger system may be via indirect heat exchange with a pre-cooling refrigerant in one or more pre-cooling heat exchangers. Pre-cooling refrigerant streams evaporated by various heat exchangers at similar pressures are combined and collected using gas liquid separators. The pre-cooling refrigerant compression stage (18) is used to compress the combined vapour flows at a plurality of different pressures. In the embodiment illustrated in FIG. 1, the pre-cooling refrigerant compression stage (18) comprises a single pre-cooling refrigerant compressor body (32) with
four suction inlets (34) arranged to receive evaporated pre-cooling refrigerant at four different pressures. It is to be understood that pre-cooling refrigerant compressor body (32) may equally be provided with any number of suction inlets (34).

In the embodiment illustrated in FIG. 2 for which like reference numerals refer to like parts, the refrigerant compression circuit (10) comprises three stages of mixed refrigerant compression (12, 14, and 16, respectively) with intercooling between each stage. A first intercooling heat exchanger (36) is arranged between the first compression stage (12) and the second compression stage (14) for removing heat of compression from the mixed refrigerant gas. When three stages of compression are used, a second intercooling heat exchanger (38) can be provided between the second and third compression stages (14 and 16, respectively) to remove the heat of compression from the mixed refrigerant between the second and third compression stages. A third heat exchanger (40) is provided downstream of the third compression stage (16) to remove the heat of compression from the refrigerant after the third compression stage. In the heat exchangers (36, 38 and 40) the compressed mixed refrigerant exchanges heat with a cooling means, by way of example, an ambient cooling fluid, such as water or air.

The embodiment illustrated in FIG. 2 differs from that illustrated in FIG. 1 in that there is no intercooling between the first compression stage (12) and the second compression stage (14) in the embodiment illustrated in FIG. 1, with intercooling only being provided between the second and third compression stages (14 and 16, respectively). The inclusion of intercooling at the outlet of the first compression stage (12) is intended to decrease the volumetric flow to the second compression stage (14), thereby decreasing the power requirement of the second compression stage (14). However if the temperature at the discharge of the first compression stage (12) is relatively low, the benefit of reducing the temperature will be small. In such cases the additional frictional pressure losses caused by the intercooling exchanger (36) may negate the cooling benefits of that exchanger, and therefore the simpler embodiment shown in FIG. 1 may be preferable to the embodiment illustrated in FIG. 2.

In the embodiments illustrated in FIG. 3 and FIG. 4 for which like reference numerals refer to like parts, the second compression stage (14) and the third compression stage (16) are combined as a first segment (42) and a second segment (44), respectively within a single back-to-back compressor body (46). This arrangement is advantageous in that the number of compressor bodies is reduced in comparison with other embodiments of the present invention, whilst still allowing the power on the first and second shafts to be matched to the power available from each driver. This arrangement is particularly suited to a circuit in which the first compression string (24) has more power available than the second compression string (30). If this is the case then the compression ratio for the first compression stage (12) can be increased, decreasing the compression ratio of the second and third compression stages (14 and 16, respectively). This allows the second and third compression stages to be combined into a single back-to-back compressor body (46) as described above.

In the embodiment illustrated in FIG. 3, the refrigerant compression circuit (10) comprises three stages of mixed refrigerant compression (12, 14, and 16, respectively) with intercooling between each stage. In the embodiment illustrated in FIG. 4, there is no intercooling between the first compression stage (12) and the second compression stage (14), with intercooling only being provided between the second and third compression stages (14 and 16, respectively).

It is to be understood that it is possible to use only two stages of mixed refrigerant compression as illustrated in FIGS. 5 and 6, for which like reference numerals refer to like parts. When there are only two stages of mixed refrigerant compression, the pre-cooling refrigerant compression stage (18) and the first compression stage (12) are arranged on the first compression string (24) driven by the first driver (22) with the second (in this case, high pressure) compression stage (14) arranged on the second compression string (30) driven by the second driver (28). The embodiments illustrated in FIGS. 5 and 6, represent a very good way to achieve a good power balance with a two-stage mixed refrigerant compression circuit when the first driver (22) has substantially more power than the second driver (28). By way of example, this arrangement would be particularly suited to a circuit in which the first driver (22) is a gas turbine, and the second driver (28) is a steam turbine running off waste heat recovered from the exhaust of the gas turbine. This arrangement may reduce fuel gas consumption as well as reduce CO₂ emissions.

The embodiment illustrated in FIG. 7 differs from that illustrated in FIG. 5 in that the mass flow of refrigerant to the second (high pressure) compression stage (14) is directed to flow through a first segment (43) and then a second segment (45), respectively within a single back-to-back compressor body (47).

In the embodiment illustrated in FIG. 7 for which like reference numerals refer to like parts, the first compression stage (12) is provided with a single compressor body (50) having a first suction inlet (52) arranged to receive a first stream (54) of refrigerant and direct the flow of the first stream (54) of refrigerant into a first segment (56), and a second suction inlet (58) arranged to receive a second stream (60) of refrigerant and direct the flow of the second stream (60) of refrigerant into a second segment (62). The first stream (54) is compressed from the first pressure to the second pressure in a first segment (56) whilst the second stream (60) is compressed from the first pressure to the second pressure in a second segment (62). The first and second segments (56 and 62, respectively) are arranged end to end such that the first and second suction inlets (52 and 58, respectively) are arranged at distal ends of the single compressor body (50). The first and second streams (54 and 60, respectively) are combined together as they flow out of a common outlet (64) positioned where the first segment (56) meets the second segment (62) of the single compressor body (50). The combined first and second streams (54 and 60, respectively) of the mass flow of refrigerant are then directed to flow into a suction inlet (66) of a single compressor body (68) in the second compression stage (14). When the refrigerant circuit (10) includes a third compression stage (16), the refrigerant gas discharged from the second compression stage (14) is directed to flow into a suction inlet (70) of a single compressor body (72) of the third compression stage (16).

A first distribution means (74) is used for splitting the mass flow of refrigerant gas to the first compression stage (12) into the first stream (54) and second stream (60), such that the first stream (54) fed to the first suction inlet (52) and the second stream (60) fed to the section suction inlet (58) are as symmetrical as possible (so the resistance to the mass flow of refrigerant through each of the first and second seg-
ments is as even as possible). One way in which symmetrical flow is achieved is to use a “branched tee” (i.e. a terminating pipe which intersects a straight run of pipe at a perpendicular angle). The flow of refrigerant enters the branched tee through one end of the terminating pipe. Half of the mass flow of refrigerant leaves the branched tee through one end of the straight run of pipe, whilst the other half of the mass flow of refrigerant leaves the branched tee in the opposite direction through the opposite distal end of the straight run of pipe. Both halves of the flow therefore perform a 90 degree angle turn. This allows the pipework to be symmetrical and therefore the mass flow rate of the first stream (54) of refrigerant fed to the first suction inlet (52) is thus substantially equal to the mass flow rate of the second stream (60) of refrigerant fed to the second suction inlet (58).

[0064] When the first compression stage (12) is provided with split flow to the first and second suction inlets (52 and 58, respectively), the maximum allowable volumetric flow rate for the combined suction flow (74) is increased. However, with this arrangement, the effective number of impellers installed in each of the first and second segments (56 and 62, respectively) of the first compression stage (12) is reduced in comparison to the number of impellers that could otherwise be installed in a single compressor body if the mass flow of refrigerant to the first compression stage was not split. Once the effective number of impellers is reduced for the first compression stage (12), the power requirement for the first compression stage (12) is reduced, thereby allowing the first compression stage (12) to be mounted coaxially on the same shaft as the compressor body (32) of the pre-cooling compression stage (18).

[0065] As the pressure increases through the compression stages, the density increases and the volumetric flow decreases. By virtue of the compression ratio, the second and third compression stages have lower actual volumetric flow rates than the first (low pressure) compression stage. By splitting the mass flow of refrigerant gas to the first compression stage (12) evenly across the first and second suction inlets (52 and 58, respectively), the volumetric flow in each of the first and second segments (56 and 62, respectively) of the first compressor body (50) is halved. As a result the actual volumetric flow to each compressor segment (56, 62, 68 and 72) is inherently more even. This has the potential to allow the volumetric flow rates to be better matched to the preferred rotational speeds of the compressor segments, thereby allowing higher efficiency.

[0066] By way of example, the suction volumetric flow of a first compression stage might typically be about ten times the volumetric flow at the suction inlet of a third compression stage. By splitting the mass flow of refrigerant to the first compression stage across the first and second suction inlets, each segment in the first compressor body of the first compression stage would only require a suction volumetric flow five times the volumetric flow of the third compression stage. By way of further example, for an LNG train producing about 6 mtpa, the suction flow inlet size for a single compressor body used for the first compression stage would need to be about 300,000 m³/h, which is greater than the largest commercially available compressor on the market at this time. Using the process of the present invention as illustrated in FIGS. 7, 8, 9 and 10, the mass flow of refrigerant to the first compression stage (12) is split across the first and second suction inlets (52 and 58, respectively), with each of the first and second compressor segments (56 and 62, respectively) being capable of compressing about 150,000 m³/h.

[0067] Splitting refrigerant flow in this way has the result that the actual volumetric flow to each of the first, second and (optional) third compression stages is more consistent, allowing better matching with the ideal rotational speed when mounted on the same shaft or a separate shafts driven by similar drivers. Also, using this arrangement in the absence of a restriction on the suction volumetric flow to the first compression stage, the LNG train size can be increased or the refrigerant circuit can be operated at a lower pressure, thereby possibly allowing greater efficiency.

[0068] In the embodiment illustrated in FIG. 8, for which like reference numerals refer to like parts, the second compression stage (14) and the third compression stage (16) are combined as a first segment (42) and a second segment (44) within a single back-to-back compressor body (46) to reduce the overall number of compressor bodies as described above in relation to FIGS. 3 and 4. The refrigerant compressor circuit is otherwise essentially the same as that illustrated in FIG. 7.

[0069] In the embodiment illustrated in FIG. 9, for which like reference numerals refer to like parts, there is no intercooling between the first stage of compression and the second stage of compression, with intercooling only being provided between the second and third compression stages. The refrigerant compressor circuit is otherwise essentially the same as that illustrated in FIG. 7. This refrigerant compressor circuit behaves like a two stage compression system rather than a three stage compression system.

[0070] In the embodiment illustrated in FIG. 10, for which like reference numerals refer to like parts, the second compression stage (14) and the third compression stage (16) are combined as a first segment (42) and a second segment (44) within a single back-to-back compressor body (46) to reduce the overall number of compressor bodies as described above in relation to FIGS. 3 and 4. The refrigerant compressor circuit is otherwise essentially the same as that illustrated in FIG. 9.

[0071] It will be apparent to persons skilled in the relevant art that numerous variations and modifications can be made without departing from the basic inventive concepts. For example, the pre-cooling refrigerant compression stage (18) may be split between two compressor bodies depending on the performance limits of each of the pre-cooling refrigerant compressors when operated in the same compression string as the first compression stage. All such modifications and variations are considered to be within the scope of the present invention, the nature of which is to be determined from the foregoing description and the appended claims.

What is claimed:
1. A refrigerant compressor circuit for use in a liquefaction plant, the refrigerant compressor circuit comprising:
   a first compression string driven by a first driver;
   a second compression string driven by a second driver;
   a pre-cooling refrigerant compression stage arranged in the first compression string to receive a stream of pre-cooling refrigerant at an inlet pressure and discharge the pre-cooling refrigerant at an outlet pressure;
   a first compression stage arranged in the first compression string to compress a mixed refrigerant gas from a first pressure to a second pressure; and,
a second compression stage arranged in the second compression string to compress the mixed refrigerant gas from the second pressure to a third pressure, wherein the pre-cooling refrigerant compression stage and the first compression stage are co-axially mounted on a first shaft drivingly coupled to a first driver in the first compression string.

2. A refrigerant compressor circuit according to claim 1, wherein a first intercooling heat exchanger is arranged between the first compression stage and the second compression stage for removing heat of compression from the mixed refrigerant gas.

3. The refrigerant circuit of claim 1, wherein the mass flow of refrigerant to the second compression stage is directed to flow through a first segment and then a second segment within a single back-to-back compressor body.

4. The refrigerant circuit of claim 1, wherein the first driver has more power than the second driver.

5. The refrigerant circuit of claim 1, wherein the first compression stage is provided with a single compressor body comprising:

   a first suction inlet arranged to receive a first stream of refrigerant and direct the flow of the first stream of refrigerant into a first segment; and

   a second suction inlet arranged to receive a second stream of refrigerant and direct the flow of the second stream of refrigerant into a second segment;

   wherein the first and second segments are arranged end to end such that the first and second suction inlets are arranged at distal ends of the single compressor body, and the first and second streams are combined together as they flow out of a common outlet of the single compressor body.

6. The refrigerant circuit of claim 5, further comprising a first distribution means for splitting the mass flow of refrigerant gas to the first compression stage into the first stream and second stream such that the first stream fed to the first suction inlet and the second stream fed to the suction suction inlet are symmetrical.

7. The refrigerant circuit of claim 6, wherein the first distribution means causes the mass flow of refrigerant to enter a branched tee such that a first half of the mass flow of refrigerant leaves the branched tee through one end of a straight run of pipe, while a second half of the mass flow of refrigerant leaves the branched tee in the opposite direction through the opposite end of the straight run of pipe.

8. The refrigerant circuit of claim 1, wherein the pre-cooling refrigerant compression stage comprises a single pre-cooling refrigerant compressor body with a plurality of suction inlets arranged to receive evaporated pre-cooling refrigerant at a corresponding plurality of different pressures.

9. The refrigerant circuit of claim 1, further comprising a third compression stage to compress the mixed refrigerant gas from the third pressure to a fourth pressure.

10. The refrigerant circuit of claim 9, wherein the second compression stage and the third compression stage are co-axially mounted on a second shaft drivingly coupled to a second driver in the second compression string.

11. The refrigerant circuit of claim 9, further comprising a second intercooling heat exchanger arranged between the second compression stage and the third compression stage, wherein the second intercooling heat exchanger is configured to remove heat of compression from the refrigerant.

12. The refrigerant circuit of claim 9, wherein the second and third compression stages are combined within a single back to back compressor body.

13. A plant for the production of a liquefied hydrocarbon product such as liquefied natural gas, the plant comprising:

   a main heat exchanger in which natural gas is liquefied by indirect heat exchange with an evaporating mixed refrigerant; and

   a refrigerant circuit to compress the evaporated refrigerant for re-use in the main heat exchanger system, the refrigerant circuit comprising:

   a first compression string driven by a first driver;

   a second compression string driven by a second driver;

   a pre-cooling refrigerant compression stage arranged in the first compression string to receive a stream of pre-cooling refrigerant at an inlet pressure and discharge the pre-cooling refrigerant at an outlet pressure;

   a first compression stage arranged in the second compression string to compress a mixed refrigerant gas from a first pressure to a second pressure; and

   a second compression stage arranged in the second compression string to compress the mixed refrigerant gas from the second pressure to a third pressure;

   wherein the pre-cooling refrigerant compression stage and the first compression stage are co-axially mounted on a first shaft drivingly coupled to a first driver in the first compression string.

14. The plant of claim 13, wherein a first intercooling heat exchanger is arranged between the first compression stage and the second compression stage to remove heat of compression from the mixed refrigerant gas.

15. The plant of claim 13, wherein the mass flow of refrigerant to the second compression stage is directed to flow through a first segment and then a second segment within a single back-to-back compressor body.

16. The plant of claim 13, wherein the first driver has more power than the second driver.

17. The plant of claim 13, wherein the first compression stage is provided with a single compressor body comprising:

   a first suction inlet arranged to receive a first stream of refrigerant and direct the flow of the first stream of refrigerant into a first segment; and

   a second suction inlet arranged to receive a second stream of refrigerant and direct the flow of the second stream of refrigerant into a second segment;

   wherein the first and second segments are arranged end to end such that the first and second suction inlets are arranged at distal ends of the single compressor body, and the first and second streams are combined together as they flow out of a common outlet of the single compressor body.

18. The plant of claim 17, further comprising a first distribution means for splitting the mass flow of refrigerant gas to the first compression stage into the first stream and second stream such that the first stream fed to the first suction inlet and the second stream fed to the section suction inlet are symmetrical.

19. The plant of claim 18, wherein the first distribution means causes the mass flow of refrigerant to enter a branched tee such that a first half of the mass flow of refrigerant leaves the branched tee through one end of a straight run of pipe, while a second half of the mass flow of refrigerant leaves the branched tee in the opposite direction through the opposite end of the straight run of pipe.
20. The plant of claim 13, wherein the pre-cooling refrigerant compression stage comprises a single pre-cooling refrigerant compressor body with a plurality of suction inlets arranged to receive evaporated pre-cooling refrigerant at a corresponding plurality of different pressures.
21. The plant of claim 13, further comprising a third compression stage to compress the mixed refrigerant gas from the third pressure to a fourth pressure.
22. The plant of claim 21, wherein the second compression stage and the third compression stage are co-axially mounted on a second shaft drivingly coupled to a second driver in the second compression string.
23. The plant of claim 21, further comprising a second intercooling heat exchanger arranged between the second compression stage and the third compression stage to remove heat of compression from the refrigerant.
24. The refrigerant circuit of claim 21, wherein the second and third compression stages are combined within a single back to back compressor body.
25. A method for cooling, preferably liquefying, a hydrocarbon stream, wherein the hydrocarbon stream is cooled by indirect heat exchange with an evaporating refrigerant, and the evaporated refrigerant is cooled using a refrigerant compressor circuit comprising:
   a first compression string driven by a first driver;
   a second compression string driven by a second driver;
   a pre-cooling refrigerant compression stage arranged in the first compression string to receive a stream of pre-cooling refrigerant at an inlet pressure and discharge the pre-cooling refrigerant at an outlet pressure;
   a first compression stage arranged in the first compression string to compress a mixed refrigerant gas from a first pressure to a second pressure; and
   a second compression stage arranged in the second compression string to compress the mixed refrigerant gas from the second pressure to a third pressure;
   wherein the pre-cooling refrigerant compression stage and the first compression stage are co-axially mounted on a first shaft drivingly coupled to a first driver in the first compression string.
26. A method according to claim 25, wherein a first intercooling heat exchanger is arranged between the first compression stage and the second compression stage to remove heat of compression from the mixed refrigerant gas.
27. A method according to claim 25, wherein the mass flow of refrigerant to the second compression stage is directed to flow through a first segment and then a second segment within a single back-to-back compressor body.
28. A method according to claim 25, wherein the first driver has more power than the second driver.
29. A method according to claim 25, wherein the first compression stage is provided with a single compressor body comprising:
   a first suction inlet arranged to receive a first stream of refrigerant and direct the flow of the first stream of refrigerant into a first segment; and
   a second suction inlet arranged to receive a second stream of refrigerant and direct the flow of the second stream of refrigerant into a second segment;
   wherein the first and second segments are arranged end to end such that the first and second suction inlets are arranged at distal ends of the single compressor body, and the first and second streams are combined together as they flow out of a common outlet of the single compressor body.
30. A method according to claim 29, wherein the refrigerant compressor circuit further comprises a first distribution means for splitting the mass flow of refrigerant gas to the first compression stage into the first stream and second stream such that the first stream fed to the first suction inlet and the second stream fed to the section suction inlet are symmetrical.
31. A method according to claim 30, wherein the first distribution means causes the mass flow of refrigerant to enter a branched tee such that a first half of the mass flow of refrigerant leaves the branched tee through one end of a straight run of pipe, while a second half of the mass flow of refrigerant leaves the branched tee in the opposite direction through the opposite end of the straight run of pipe.
32. A method according to claim 25, wherein the pre-cooling refrigerant compression stage comprises a single pre-cooling refrigerant compressor body with a plurality of suction inlets arranged to receive evaporated pre-cooling refrigerant at a corresponding plurality of different pressures.
33. A method according to claim 25, wherein the refrigerant compressor circuit further comprises a third compression stage to compress the mixed refrigerant gas from the third pressure to a fourth pressure.
34. A method according to claim 33, wherein the second compression stage and the third compression stage are co-axially mounted on a second shaft drivingly coupled to a second driver in the second compression string.
35. A method according to claim 33, wherein the refrigerant compressor circuit further comprises a second intercooling heat exchanger arranged between the second compression stage and the third compression stage to remove heat of compression from the refrigerant.
36. A method according to claim 33, wherein the second and third compression stages are combined within a single back to back compressor body.

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