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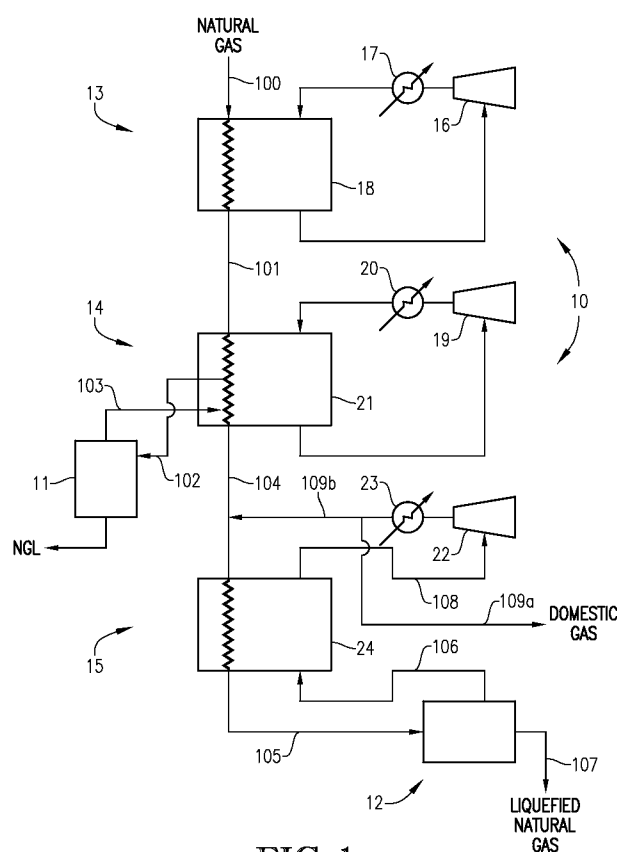


FIG. 1

(57) Abstract: An LNG facility capable of producing a domestic gas product from an intermediate stream in the LNG facility. Withdrawing the domestic gas product from a location within the LNG facility can minimize operational disturbances typically caused by extracting a domestic gas product stream upstream of the liquefaction portion of the LNG facility. In addition, withdrawing the domestic gas product from this location can provide increased control of light contaminants (e.g., nitrogen) in open-loop refrigeration cycles and can ultimately result in incremental LNG and/or NGL production.

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DOMESTIC GAS PRODUCT FROM AN LNG FACILITY

BACKGROUND OF THE INVENTION

1. Field of the Invention

5 This invention relates to methods and apparatuses for liquefying natural gas. In another aspect, the invention concerns an LNG facility capable of simultaneously producing liquefied natural gas (LNG) and a domestic gas product.

2. Description of the Prior Art

10 Cryogenic liquefaction is commonly used to convert natural gas into a more convenient form for transportation and/or storage. Because liquefying natural gas greatly reduces its specific volume, large quantities of natural gas can be economically transported and/or stored in liquefied form.

Transporting natural gas in its liquefied form can effectively link a natural gas source with a distant market when the source and market are not connected by a pipeline.
15 This situation commonly arises when the source of natural gas and the market for the natural gas are separated by large bodies of water. In such cases, LNG can be transported from the source to the market using specially designed ocean-going LNG tankers.

Storing natural gas in its liquefied form can help balance out periodic fluctuations
20 in natural gas supply and demand. In particular, LNG can be "stockpiled" for use when natural gas demand is low and/or supply is high. As a result, future demand peaks can be met with LNG from storage, which can be vaporized as demand requires.

Several methods exist for liquefying natural gas. Some methods produce a pressurized LNG (PLNG) product that is useful, but requires expensive pressure-
25 containing vessels for storage and transportation. Other methods produce an LNG product having a pressure at or near atmospheric pressure. In general, these non-pressurized LNG production methods involve cooling a natural gas stream via indirect heat exchange with one or more refrigerants and then expanding the cooled natural gas stream to near atmospheric pressure. In addition, most LNG facilities employ one or
30 more systems to remove contaminants (e.g., water, acid gases, nitrogen, and ethane and heavier components) from the natural gas stream at different points during the liquefaction process.

In addition to LNG, some LNG facilities also produce a domestic gas product. As used herein, the term "domestic gas product" refers to any gaseous, predominantly

methane stream originating from an LNG facility that is routed to a location external to the LNG facility for sale and/or use. Typically, domestic gas products from LNG facilities are transported via pipeline to the local natural gas market for subsequent sale. The domestic gas product from most LNG facilities originates as a slip stream of the natural gas feed entering the liquefaction portion of the LNG facility. In order to ensure the domestic gas product meets certain pipeline specifications (e.g., hydrocarbon dew point), the withdrawn natural gas stream is often subjected to further processing (e.g., distillation) in order to produce a compliant domestic gas product. Often, the remaining portion of the domestic gas stream is recombined with the natural gas feed stream entering the LNG facility, a practice which can cause in drastic changes in the composition of the natural gas feed. These drastic changes can adversely affect the operation of the LNG facility and can ultimately result in off-spec LNG product and/or reduced LNG production.

Thus, a need exists for an LNG facility that is capable of efficiently and consistently producing on-spec LNG and a pipeline-compliant domestic gas product without requiring additional process equipment in order to maximize facility production while minimizing capital and operating costs.

SUMMARY OF THE INVENTION

In one embodiment of the present invention, there is provided a process for liquefying a natural gas stream in an LNG facility, the process comprising: (a) cooling at least a portion of the natural gas stream in a first refrigeration cycle via indirect heat exchange with a predominantly methane refrigerant; (b) flashing at least a portion of the cooled natural gas stream to thereby provide a predominantly liquid product stream and a predominantly vapor refrigerant stream; (c) compressing at least a portion of the predominantly vapor refrigerant stream to thereby provide a compressed refrigerant stream; and (d) separating at least a portion of the compressed refrigerant stream into a domestic gas fraction and a compressed refrigerant fraction.

In another embodiment of the present invention, there is provided a process for liquefying a natural gas stream in an LNG facility, the process comprising: (a) cooling at least a portion of the natural gas stream in an upstream refrigeration cycle of the LNG facility via indirect heat exchange with an upstream refrigerant to thereby provide a cooled natural gas stream; (b) further cooling at least a portion of the cooled natural gas stream via indirect heat exchange with a predominantly methane refrigerant stream in a

methane refrigeration cycle to thereby produce a further cooled natural gas stream and a warmed refrigerant stream; (c) separating at least a portion of the warmed refrigerant stream into a domestic gas fraction and a refrigerant fraction; and (d) cooling at least a portion of the refrigerant fraction in the upstream refrigeration cycle via indirect heat exchange with the upstream refrigerant.

In yet another embodiment of the present invention, there is provided a process for liquefying a natural gas stream in an LNG facility, the process comprising: (a) cooling the natural gas stream in a first refrigeration cycle via indirect heat exchange with a first refrigerant to thereby produce a cooled predominantly methane stream; (b) separating at least a portion of the cooled predominantly methane stream in a distillation column to thereby produce a heavies-rich stream and a heavies-depleted stream; (c) subjecting at least a portion of the heavies-depleted stream to expansion cooling to thereby produce LNG having a pressure in the range of from about 0 to about 40 psia; and (d) prior to at least a portion of the expansion cooling of step (c), withdrawing a domestic gas fraction from the heavies-depleted stream.

In a still further embodiment of the present invention, there is provided an LNG facility for liquefying a natural gas stream. The LNG facility comprises an open-loop refrigeration cycle operable to cool at least a portion of the natural gas stream via indirect heat exchange with a first refrigerant. The open-loop refrigeration cycle comprises a first heat exchanger defining a first cooling pass and a first refrigerant pass. The first heat exchanger is operable to cool at least a portion of the natural gas stream in the first cooling pass via indirect heat exchange with the first refrigerant in the first refrigerant pass. The open-loop refrigeration cycle also comprises an expander defining an expander inlet and an expander outlet. The expander inlet is in fluid communication with the first cooling pass. The open-loop refrigeration cycle further comprises a vapor-liquid separator defining a separator inlet, a lower liquid outlet, and an upper vapor outlet. The separator inlet is coupled in fluid flow communication with the expander outlet and the upper vapor outlet is coupled in fluid flow communication with the first refrigerant pass. The open-loop refrigeration cycle also comprises a first refrigerant compressor defining an inlet port and an outlet port. The inlet port is coupled in fluid flow communication with the first refrigerant pass. The open-loop refrigeration cycle additionally comprises a compressed refrigerant conduit for routing fluid flow from the outlet port of the compressor to a location within the LNG facility and a domestic gas

conduit for routing fluid flow from the outlet port of the compressor and/or the compressed refrigerant conduit to a location outside the LNG facility.

BRIEF DESCRIPTION OF THE DRAWINGS

5 Certain embodiments of the present invention are described in detail below with reference to the enclosed figures, wherein:

FIG. 1 is a simplified overview of a cascade-type LNG facility in configured in accordance with one embodiment of the present invention; and

10 FIG. 2 is a schematic diagram a cascade-type LNG facility configured in accordance with one embodiment of present invention.

DETAILED DESCRIPTION

The present invention can be implemented in a facility used to cool natural gas to its liquefaction temperature to thereby produce liquefied natural gas (LNG). The LNG
15 facility generally employs one or more refrigerants to extract heat from the natural gas and then reject the heat to the environment. Numerous configurations of LNG systems exist, and the present invention may be implemented many different types of LNG systems.

In one embodiment, the present invention can be implemented in a mixed
20 refrigerant LNG system. Examples of mixed refrigerant processes can include, but are not limited to, a single refrigeration system using a mixed refrigerant, a propane pre-cooled mixed refrigerant system, and a dual mixed refrigerant system.

In another embodiment, the present invention is implemented in a cascade LNG system employing a cascade-type refrigeration process using one or more pure
25 component refrigerants. The refrigerants utilized in cascade-type refrigeration processes can have successively lower boiling points in order to maximize heat removal from the natural gas stream being liquefied. Additionally, cascade-type refrigeration processes can include some level of heat integration. For example, a cascade-type refrigeration process can cool one or more refrigerants having a higher volatility via indirect heat
30 exchange with one or more refrigerants having a lower volatility. In addition to cooling the natural gas stream via indirect heat exchange with one or more refrigerants, cascade and mixed-refrigerant LNG systems can employ one or more expansion cooling stages to simultaneously cool the LNG while reducing its pressure to near atmospheric pressure.

FIG. 1 illustrates one embodiment of a simplified LNG facility capable of simultaneously producing LNG and a domestic gas product. The cascade-type LNG facility of FIG. 1 generally comprises a cascade cooling section 10, a heavies removal zone 11, and an expansion cooling section 12. Cascade cooling section 10 is depicted as comprising a first mechanical refrigeration cycle 13, a second mechanical refrigeration cycle 14, and a third mechanical refrigeration cycle 15. In general, first, second, and third refrigeration cycles 13, 14, 15 can be closed-loop refrigeration cycles, open-loop refrigeration cycles, or any combination thereof. In one embodiment of the present invention, first and second refrigeration cycles 13 and 14 can be closed-loop cycles, and third refrigeration cycle 15 can be an open-loop cycle that utilizes a refrigerant comprising at least a portion of the natural gas feed stream undergoing liquefaction.

In accordance with one embodiment of the present invention, first, second, and third refrigeration cycles 13, 14, 15 can employ respective first, second, and third refrigerants having successively lower boiling points. For example, the first, second, and third refrigerants can have mid-range boiling points at standard pressure (i.e., mid-range standard boiling points) within about 20°F, within about 10°F, or within 5°F of the standard boiling points of propane, ethylene, and methane, respectively. In one embodiment, the first refrigerant can comprise at least about 75 mole percent, at least about 90 mole percent, at least 95 mole percent, or can consist essentially of propane, propylene, or mixtures thereof. The second refrigerant can comprise at least about 75 mole percent, at least about 90 mole percent, at least 95 mole percent, or can consist essentially of ethane, ethylene, or mixtures thereof. The third refrigerant can comprise at least about 75 mole percent, at least about 90 mole percent, at least 95 mole percent, or can consist essentially of methane.

As shown in FIG. 1, first refrigeration cycle 13 can comprise a first refrigerant compressor 16, a first cooler 17, and a first refrigerant chiller 18. First refrigerant compressor 16 can discharge a stream of compressed first refrigerant, which can subsequently be cooled and at least partially liquefied in cooler 17. The resulting refrigerant stream can then enter first refrigerant chiller 18, wherein at least a portion of the refrigerant stream can cool the incoming natural gas stream in conduit 100 via indirect heat exchange with the vaporizing first refrigerant. The gaseous refrigerant can exit first refrigerant chiller 18 and can then be routed to an inlet port of first refrigerant compressor 16 to be recirculated as previously described.

First refrigerant chiller 18 can comprise one or more cooling stages operable to reduce the temperature of the incoming natural gas stream in conduit 100 by about 40 to about 210°F, about 50 to about 190°F, or 75 to 150°F. Typically, the natural gas entering first refrigerant chiller 24 via conduit 100 can have a temperature in the range of from about 0 to about 200°F, about 20 to about 180°F, or 50 to 165°F, while the temperature of the cooled natural gas stream exiting first refrigerant chiller 18 can be in the range of from about -65 to about 0°F, about -50 to about -10°F, or -35 to -15°F. In general, the pressure of the natural gas stream in conduit 100 can be in the range of from about 100 to about 3,000 pounds per square inch absolute (psia), about 250 to about 1,000 psia, or 400 to 800 psia. Because the pressure drop across first refrigerant chiller 18 can be less than about 100 psi, less than about 50 psi, or less than 25 psi, the cooled natural gas stream in conduit 101 can have substantially the same pressure as the natural gas stream in conduit 100.

As illustrated in FIG. 1, the cooled natural gas stream (also referred to herein as the “cooled predominantly methane stream”) exiting first refrigeration cycle 13 can then enter second refrigeration cycle 14, which can comprise a second refrigerant compressor 19, a second cooler 20, and a second refrigerant chiller 21. Compressed refrigerant can be discharged from second refrigerant compressor 19 and can subsequently be cooled and at least partially liquefied in cooler 20 prior to entering second refrigerant chiller 21. Second refrigerant chiller 21 can employ a plurality of cooling stages to progressively reduce the temperature of the predominantly methane stream in conduit 101 by about 50 to about 180°F, about 65 to about 150°F, or 95 to 125°F via indirect heat exchange with the vaporizing second refrigerant. As shown in FIG. 1, the vaporized second refrigerant can then be returned to an inlet port of second refrigerant compressor 19 prior to being recirculated in second refrigeration cycle 14, as previously described.

The natural gas feed stream in conduit 100 will usually contain ethane and heavier components (C_2+), which can result in the formation of a C_2+ rich liquid phase in one or more of the cooling stages of second refrigeration cycle 14. In order to remove the undesired heavies material from the predominantly methane stream prior to complete liquefaction, at least a portion of the natural gas stream passing through second refrigerant chiller 21 can be withdrawn via conduit 102 and processed in heavies removal zone 11, as shown in FIG. 1. The natural gas stream in conduit 102 can have a temperature in the range of from about -160 to about -50°F, about -140 to about -65°F, or

-115 to -85°F and a pressure that is within about 5 percent, about 10 percent, or 15 percent of the pressure of the natural gas feed stream in conduit 100.

Heavies removal zone 11 can comprise one or more gas-liquid separators operable to remove at least a portion of the heavy hydrocarbon material from the predominantly methane stream. Typically, heavies removal zone 11 can be operated to remove benzene and other high molecular weight aromatic components, which will freeze in subsequent liquefaction steps and plug downstream process equipment. In addition, heavies removal zone 11 can be operated to recover the heavy hydrocarbons as a natural gas liquids (NGL) product stream. Examples of typical hydrocarbon components comprising NGL streams can include ethane, propane, butane isomers, pentane isomers, and hexane and heavier components (i.e., C₆+). The extent of NGL recovery from the predominantly methane stream can ultimately impact one or more final characteristics of the LNG product, such as, for example, Wobbe index, BTU content, higher heating value (HHV), ethane content, and the like. In one embodiment, the NGL product stream exiting heavies removal zone 11 can be subjected to further fractionation in order to produce one or more pure component streams. Often, NGL product streams and/or their constituents can be used as gasoline blendstock.

The predominantly methane stream exiting heavies removal zone 11 via conduit 103 can comprise less than about 1 weight percent, less than about 0.5 weight percent, less than about 0.1 weight percent, or less than 0.01 weight percent of C₆+ material, based on the total weight of the stream. Typically, the predominantly methane stream in conduit 103 can have a temperature in the range of from about -140 to about -50°F, about -125 to about -60°F, or -110 to -75°F and a pressure in the range of from about 200 to about 1,200 psia, about 350 to about 850 psia, or 500 to 700 psia. As shown in FIG. 1, the stream exiting heavies removal zone 12 via conduit 103 can subsequently be routed back to second refrigeration cycle 14, wherein the stream can be further cooled via second refrigerant chiller 21. In one embodiment, the stream exiting second refrigerant chiller 21 via conduit 104 can be completely liquefied and can have a temperature in the range of from about -205 to about -70°F, about -175 to about -95°F, or -140 to -125°F. Generally, the stream in conduit 104 can be at approximately the same pressure the natural gas stream entering the LNG facility in conduit 100.

As illustrated in FIG. 1, the pressurized LNG-bearing stream in conduit 104 enters third refrigeration cycle 15, which is depicted as generally comprising a third refrigerant compressor 22, a cooler 23, and a third refrigerant chiller 24. Compressed

refrigerant discharged from third refrigerant compressor 22 enters cooler 23, wherein the refrigerant stream is cooled and at least partially liquefied prior to entering third refrigerant chiller 24. Third refrigerant chiller 24 can comprise one or more cooling stages operable to subcool the pressurized predominantly methane stream via indirect heat exchange with the vaporizing refrigerant. In one embodiment, the temperature of the pressurized LNG-bearing stream can be reduced by about 2 to about 60°F, about 5 to about 50°F, or 10 to 40°F in third refrigerant chiller 24. In general, the temperature of the pressurized LNG-bearing stream exiting third refrigerant chiller 24 via conduit 105 can be in the range of from about -275 to about -75°F, about -225 to about -100°F, or -200 to -125°F.

As shown in FIG. 1, the pressurized LNG-bearing stream in conduit 105 can be then routed to expansion cooling section 12, wherein the stream is sub-cooled via sequential pressure reduction to near atmospheric pressure by passage through one or more expansion stages. In one embodiment, each expansion stage can reduce the temperature of the LNG-bearing stream by about 10 to about 60°F, about 15 to about 50°F, or 20 to 40°F. Each expansion stage comprises one or more expanders, which reduce the pressure of the liquefied stream to thereby evaporate or flash a portion thereof. Examples of suitable expanders can include, but are not limited to, Joule-Thompson valves, venturi nozzles, and turboexpanders. Expansion section 12 can employ any number of expansion stages and one or more expansion stages may be integrated with one or more cooling stages of third refrigerant chiller 24. In one embodiment of the present invention, expansion section 12 can reduce the pressure of the LNG-bearing stream in conduit 105 by about 75 to about 450 psi, about 125 to about 300 psi, or 150 to 225 psi.

Each expansion stage may additionally employ one or more vapor-liquid separators operable to separate the vapor phase (i.e., the flash gas stream) from the cooled liquid stream. As previously discussed, third refrigeration cycle 15 can comprise an open-loop refrigeration cycle, closed-loop refrigeration cycle, or any combination thereof. When third refrigeration cycle 15 comprises a closed-loop refrigeration cycle, the flash gas stream can be used as fuel within the facility or routed downstream for storage, further processing, and/or disposal. When third refrigeration cycle 15 comprises an open-loop refrigeration cycle, at least a portion of the flash gas stream exiting expansion section 12 can be used as a refrigerant to cool at least a portion of the natural gas stream in conduit 104. Generally, when third refrigerant cycle 15 comprises an

open-loop cycle, the third refrigerant can comprise at least 50 weight percent, at least about 75 weight percent, or at least 90 weight percent of flash gas from expansion section 12, based on the total weight of the stream. As illustrated in FIG. 1, the flash gas exiting expansion section 12 via conduit 106 can enter third refrigerant chiller 24, wherein the stream can cool at least a portion of the natural gas stream entering third refrigerant chiller 24 via conduit 104. The resulting warmed refrigerant stream can then exit third refrigerant chiller 24 via conduit 108 and can thereafter be routed to an inlet port of third refrigerant compressor 22.

As shown in FIG. 1, third refrigerant compressor 22 discharges a stream of compressed third refrigerant, which is thereafter cooled in cooler 23. The cooled refrigerant stream can then be split into two portions. The first portion in conduit 109a can comprise the domestic gas product stream and can subsequently be routed to a location external to the LNG facility depicted in FIG. 1. The second portion of cooled refrigerant in conduit 109b can combine with the natural gas stream in conduit 104 prior to re-entering third refrigerant chiller 24, as previously discussed.

As shown in FIG. 1, the liquid stream exiting expansion section 12 via conduit 107 comprises LNG. In one embodiment, the LNG in conduit 107 can have a temperature in the range of from about -200 to about -300°F, about -225 to about -275°F, or -240 to -260°F and a pressure in the range of from about 0 to about 40 psia, about 5 to about 25 psia, or 10 to 20 psia. The LNG in conduit 107 can subsequently be routed to storage and/or shipped to another location via pipeline, ocean-going vessel, truck, or any other suitable transportation means. In one embodiment, at least a portion of the LNG can be subsequently vaporized for uses in applications requiring vapor-phase natural gas.

In addition to producing LNG in conduit 107, the LNG facility depicted in FIG. 1 can also produce a domestic gas product in conduit 109a. As shown in FIG. 1, the domestic gas product can be withdrawn from an intermediate stream within the LNG facility, typically at a location downstream of heavies removal zone 95. Because the domestic gas stream can be withdrawn downstream of heavies removal zone 95, the domestic gas product can have a concentration of C₆+ material that is less than about 1 weight percent, less than about 0.5 weight percent, less than about 0.1 weight percent, or less than 0.01 weight percent, based on the total weight of the domestic gas stream. As a result, the domestic gas product withdrawn from the LNG facility of FIG. 1 via conduit 109a can comply with most or all of the local natural gas pipeline product specifications, including, for example, hydrocarbon dew point, with little or no additional processing.

In one embodiment shown in FIG. 1, the domestic gas product stream can be withdrawn from the compressed third refrigerant stream exiting third refrigerant compressor 22 via conduit 109a. Typically, the pressure of the domestic gas stream can be in the range of from about 15 to about 100 bar gauge (barg), about 25 to about 90 barg, or 35 to 75 barg. In order to produce a domestic gas product having a mass flow rate that is at least about 2 percent, at least about 5 percent, at least about 10 percent, or at least 25 percent of the mass flow rate of the total compressed third refrigerant stream exiting third refrigerant compressor 22, the LNG facility of FIG. 1 can process additional natural gas feed. By processing additional feed gas, additional refrigeration duty can be recovered in the third refrigeration cycle, which can ultimately result in incremental LNG and/or NGL production. In addition, when the domestic gas product is withdrawn from an open-loop cycle, as illustrated in FIG. 1, producing a domestic gas stream can help control the concentration of light contaminants (e.g., nitrogen) in the refrigeration loop, thereby allowing the LNG facility increased processing flexibility. Further, because of the relatively low concentration of heavies and other contaminants in the domestic gas product in conduit 109a, at least a portion of the domestic gas product can subsequently be blended with an unprocessed or off-spec domestic gas stream from another source (not shown) in order to produce a saleable domestic gas product. Optionally, one or more fuel gas streams (not shown) for use within the LNG facility can be withdrawn from the domestic gas stream and/or the compressed refrigerant stream in conduits 109a, 109b. Typically, at least a portion of the fuel gas stream can be used to power one or more gas turbine used to drive at least one refrigerant compressor.

FIG. 2 presents one embodiment of a specific configuration of the LNG facility shown in FIG. 1. While "propane," "ethylene," and "methane" are used to refer to respective first, second, and third refrigerants, it should be understood that the embodiment illustrated in FIG. 2 and described herein can apply to any combination of suitable refrigerants. The LNG facility depicted in FIG. 2 generally comprises a propane refrigeration cycle 30, an ethylene refrigeration cycle 50, a methane refrigeration cycle 70 with an expansion section 80, and a heavies removal zone 95. To facilitate an understanding of FIG. 2, the following numeric nomenclature was employed. Items numbered 31 through 49 are process vessels and equipment directly associated with propane refrigeration cycle 30, and items numbered 51 through 69 are process vessels and equipment related to ethylene refrigeration cycle 50. Items numbered 71 through 94 correspond to process vessels and equipment associated with methane refrigeration cycle

70 and/or expansion section 80. Items numbered 96 through 99 are process vessels and equipment associated with heavies removal zone 95. Items numbered 100 through 199 correspond to flow lines or conduits that contain predominantly methane streams. Items numbered 200 through 299 correspond to flow lines or conduits which contain predominantly ethylene streams. Items numbered 300 through 399 correspond to flow lines or conduits that contain predominantly propane streams.

Referring to FIG. 2, the main components of propane refrigeration cycle 30 include a propane compressor 31, a propane cooler 32, a high-stage propane chiller 33, an intermediate stage propane chiller 34, and a low-stage propane chiller 35. The main components of ethylene refrigeration cycle 50 include an ethylene compressor 51, an ethylene cooler 52, a high-stage ethylene chiller 53, an intermediate-stage ethylene chiller 54, a low-stage ethylene chiller/condenser 55, and an ethylene economizer 56. The main components of methane refrigeration cycle 70 include a methane compressor 71, a methane cooler 72, a main methane economizer 73, and a secondary methane economizer 74. The main components of expansion section 80 include a high-stage methane expander 81, a high-stage methane flash drum 82, an intermediate-stage methane expander 83, an intermediate-stage methane flash drum 84, a low-stage methane expander 85, and a low-stage methane flash drum 86. The LNG facility of FIG. 2 also includes heavies removal zone 95 downstream of intermediate stage ethylene chiller 54 for removing heavy hydrocarbon components from the processed natural gas and recovering the resulting natural gas liquids. The heavies removal zone 95 of FIG. 2 is shown as generally comprising a first distillation column 96 and a second distillation column 97.

The operation of the LNG facility illustrated in FIG. 2 will now be described in more detail, beginning with propane refrigeration cycle 30. Propane is compressed in multi-stage (e.g., three-stage) propane compressor 31 driven by, for example, a gas turbine driver 31a. The three stages of compression preferably exist in a single unit, although each stage of compression may be a separate unit and the units mechanically coupled to be driven by a single driver. Upon compression, the propane is passed through conduit 300 to propane cooler 32, wherein it is cooled and liquefied via indirect heat exchange with an external fluid (e.g., air or water). A representative temperature and pressure of the liquefied propane refrigerant exiting cooler 32 is about 100°F and about 190 psia. The stream from propane cooler 32 can then be passed through conduit 302 to a pressure reduction means, illustrated as expansion valve 36, wherein the

pressure of the liquefied propane is reduced, thereby evaporating or flashing a portion thereof. The resulting two-phase stream then flows via conduit 304 into high-stage propane chiller 33. High stage propane chiller 33 uses indirect heat exchange means 37, 38, and 39 to cool respectively, the incoming gas streams, including a yet-to-be-discussed methane refrigerant stream in conduit 112, a natural gas feed stream in conduit 110, and a yet-to-be-discussed ethylene refrigerant stream in conduit 202 via indirect heat exchange with the vaporizing refrigerant. The cooled methane refrigerant stream exits high-stage propane chiller 33 via conduit 130 and can subsequently be routed to the inlet of main methane economizer 73, which will be discussed in greater detail in a subsequent section.

The cooled natural gas stream from high-stage propane chiller 33 (also referred to herein as the "methane-rich stream") flows via conduit 114 to a separation vessel 40, wherein the gaseous and liquid phases are separated. The liquid phase, which can be rich in propane and heavier components (C_3+), is removed via conduit 303. The predominately vapor phase exits separator 40 via conduit 116 and can then enter intermediate-stage propane chiller 34, wherein the stream is cooled in indirect heat exchange means 41 via indirect heat exchange with a yet-to-be-discussed propane refrigerant stream. The resulting two-phase methane-rich stream in conduit 118 can then be routed to low-stage propane chiller 35, wherein the stream can be further cooled via indirect heat exchange means 42. The resultant predominantly methane stream can then exit low-stage propane chiller 34 via conduit 120. Subsequently, the cooled methane-rich stream in conduit 120 can be routed to high-stage ethylene chiller 53, which will be discussed in more detail shortly.

The vaporized propane refrigerant exiting high-stage propane chiller 33 is returned to the high-stage inlet port of propane compressor 31 via conduit 306. The residual liquid propane refrigerant in high-stage propane chiller 33 can be passed via conduit 308 through a pressure reduction means, illustrated here as expansion valve 43, whereupon a portion of the liquefied refrigerant is flashed or vaporized. The resulting cooled, two-phase refrigerant stream can then enter intermediate-stage propane chiller 34 via conduit 310, thereby providing coolant for the natural gas stream and yet-to-be-discussed ethylene refrigerant stream entering intermediate-stage propane chiller 34. The vaporized propane refrigerant exits intermediate-stage propane chiller 34 via conduit 312 and can then enter the intermediate-stage inlet port of propane compressor 31. The remaining liquefied propane refrigerant exits intermediate-stage propane chiller 34 via

conduit 314 and is passed through a pressure-reduction means, illustrated here as expansion valve 44, whereupon the pressure of the stream is reduced to thereby flash or vaporize a portion thereof. The resulting vapor-liquid refrigerant stream then enters low-stage propane chiller 35 via conduit 316 and cools the methane-rich and yet-to-be-discussed ethylene refrigerant streams entering low-stage propane chiller 35 via conduits 118 and 206, respectively. The vaporized propane refrigerant stream then exits low-stage propane chiller 35 and is routed via conduit 318 to the low-stage inlet port of propane compressor 31, wherein the stream is compressed and recycled as previously described.

As shown in FIG. 2, a stream of ethylene refrigerant in conduit 202 enters high-stage propane chiller, wherein the ethylene stream is cooled via indirect heat exchange means 39. The resulting cooled stream in conduit 204 then exits high-stage propane chiller 33, whereafter the at least partially condensed stream enters intermediate-stage propane chiller 34. Upon entering intermediate-stage propane chiller 34, the ethylene refrigerant stream can be further cooled via indirect heat exchange means 45. The resulting two-phase ethylene stream can then exit intermediate-stage propane chiller 34 prior to entering low-stage propane chiller 35 via conduit 206. In low-stage propane chiller 35, the ethylene refrigerant stream can be at least partially condensed, or condensed in its entirety, via indirect heat exchange means 46. The resulting stream exits low-stage propane chiller 35 via conduit 208 and can subsequently be routed to a separation vessel 47, wherein the vapor portion of the stream, if present, can be removed via conduit 210. The liquefied ethylene refrigerant stream exiting separator 47 via conduit 212 can have a representative temperature and pressure of about -24°F and about 285 psia.

Turning now to ethylene refrigeration cycle 50 in FIG. 2, the liquefied ethylene refrigerant stream in conduit 212 can enter ethylene economizer 56, wherein the stream can be further cooled by an indirect heat exchange means 57. The sub-cooled liquid ethylene stream in conduit 214 can then be routed through a pressure reduction means, illustrated here as expansion valve 58, whereupon the pressure of the stream is reduced to thereby flash or vaporize a portion thereof. The cooled, two-phase stream in conduit 215 can then enter high-stage ethylene chiller 53, wherein at least a portion of the ethylene refrigerant stream can vaporize to thereby cool the methane-rich stream entering an indirect heat exchange means 59 of high-stage ethylene chiller 53 via conduit 120. The vaporized and remaining liquefied refrigerant exit high-stage ethylene chiller 53 via

respective conduits 216 and 220. The vaporized ethylene refrigerant in conduit 216 can re-enter ethylene economizer 56, wherein the stream can be warmed via an indirect heat exchange means 60 prior to entering the high-stage inlet port of ethylene compressor 51 via conduit 218, as shown in FIG. 2.

5 The remaining liquefied refrigerant in conduit 220 can re-enter ethylene economizer 56, wherein the stream can be further sub-cooled by an indirect heat exchange means 61. The resulting cooled refrigerant stream exits ethylene economizer 56 via conduit 222 and can subsequently be routed to a pressure reduction means, illustrated here as expansion valve 62, whereupon the pressure of the stream is reduced
10 to thereby vaporize or flash a portion thereof. The resulting, cooled two-phase stream in conduit 224 enters intermediate-stage ethylene chiller 54, wherein the refrigerant stream can cool the natural gas stream in conduit 122 entering intermediate-stage ethylene chiller 54 via an indirect heat exchange means 63. As shown in FIG. 2, the resulting cooled methane-rich stream exiting intermediate stage ethylene chiller 54 can then be
15 routed to heavies removal zone 95 via conduit 124. Heavies removal zone 95 will be discussed in detail in a subsequent section.

 The vaporized ethylene refrigerant exits intermediate-stage ethylene chiller 54 via conduit 226, whereafter the stream can combine with a yet-to-be-discussed ethylene vapor stream in conduit 238. The combined stream in conduit 239 can then enter
20 ethylene economizer 56, wherein the stream is warmed in an indirect heat exchange means 64 prior to being fed into the low-stage inlet port of ethylene compressor 51 via conduit 230. Ethylene compressor 51 can be driven by, for example, a gas turbine driver 51a. Ethylene compressor 51 comprises at least one stage of compression, and, when multiple stages are employed, the stages can exist in a single unit or can be separate units
25 mechanically coupled to a common driver. Generally, when ethylene compressor 71 comprises two or more compression stages, one or more intercoolers (not shown) can be provided between subsequent compression stages. As shown in FIG. 2, a stream of compressed ethylene refrigerant in conduit 236 can subsequently be routed to ethylene cooler 52, wherein the ethylene stream can be cooled via indirect heat exchange with an
30 external fluid (e.g., water or air). The resulting, at least partially condensed ethylene stream can then be introduced via conduit 202 into high-stage propylene chiller 33 for additional cooling as previously described.

 The remaining liquefied ethylene refrigerant exits intermediate-stage ethylene chiller 54 via conduit 228 prior to entering low-stage ethylene chiller/condenser 55,

wherein the refrigerant can cool the methane-rich stream entering low-stage ethylene chiller/condenser via conduit 128 in an indirect heat exchange means 65. In one embodiment shown in FIG. 2, the stream in conduit 128 results from the combination of a heavies-depleted (i.e., light hydrocarbon rich) stream exiting heavies removal zone 95 via conduit 126 and a yet-to-be-discussed methane refrigerant stream in conduit 168. As shown in FIG. 2, the vaporized ethylene refrigerant can then exit low-stage ethylene chiller/condenser 55 via conduit 238 prior to combining with the vaporized ethylene exiting intermediate-stage ethylene chiller 54 via conduit 226 and entering the low-stage inlet port of ethylene compressor 51, as previously discussed.

The cooled natural gas stream exiting low-stage ethylene chiller/condenser in conduit 132 can also be referred to as the "pressurized LNG-bearing stream." As shown in FIG. 2, the pressurized LNG-bearing stream exits low-stage ethylene chiller/condenser 55 via conduit 132 prior to entering main methane economizer 73. In main methane economizer 73, the methane-rich stream can be cooled in an indirect heat exchange means 75 via indirect heat exchange with one or more yet-to-be discussed methane refrigerant streams. The cooled, pressurized LNG-bearing stream exits main methane economizer 73 and can then be routed via conduit 134 into expansion section 80 of methane refrigeration cycle 70. In expansion section 80, the cooled predominantly methane stream passes through high-stage methane expander 81, whereupon the pressure of the stream is reduced to thereby vaporize or flash a portion thereof. The resulting two-phase methane-rich stream in conduit 136 can then enter high-stage methane flash drum 82, whereupon the vapor and liquid portions can be separated. The vapor portion exiting high-stage methane flash drum 82 (i.e., the high-stage flash gas) via conduit 143 can then enter main methane economizer 73, wherein the stream is heated via indirect heat exchange means 76. The resulting warmed vapor stream exits main methane economizer 73 via conduit 138 and subsequently combines with a yet-to-be-discussed vapor stream exiting heavies removal zone 95 in conduit 140. The combined stream in conduit 141 can then be routed to the high-stage inlet port of methane compressor 71, as shown in FIG. 2.

The liquid phase exiting high-stage methane flash drum 82 via conduit 142 can enter secondary methane economizer 74, wherein the methane stream can be cooled via indirect heat exchange means 92. The resulting cooled stream in conduit 144 can then be routed to a second expansion stage, illustrated here as intermediate-stage expander 83, wherein the pressure of the stream can be reduced to thereby evaporate or flash a portion

thereof. The resulting two-phase methane-rich stream in conduit 146 can then enter intermediate-stage methane flash drum 84, wherein the liquid and vapor portions of the stream can be separated and can exit the intermediate-stage flash drum via respective conduits 148 and 150. The vapor portion (i.e., the intermediate-stage flash gas) in conduit 150 can re-enter secondary methane economizer 74, wherein the stream can be heated via an indirect heat exchange means 87. The warmed stream can then be routed via conduit 152 to main methane economizer 73, wherein the stream can be further warmed via an indirect heat exchange means 77 prior to entering the intermediate-stage inlet port of methane compressor 71 via conduit 154.

The liquid stream exiting intermediate-stage methane flash drum 84 via conduit 148 can then pass through a low-stage expander 85, whereupon the pressure of the liquefied methane-rich stream can be further reduced to thereby vaporize or flash a portion thereof. The resulting cooled, two-phase stream in conduit 156 can then enter low-stage methane flash drum 86, wherein the vapor and liquid phases can be separated. The liquid stream exiting low-stage methane flash drum 86 can comprise the liquefied natural gas (LNG) product. The LNG product, which is at about atmospheric pressure, can be routed via conduit 158 downstream for subsequent storage, transportation, and/or use.

The vapor stream exiting low-stage methane flash drum 86 (i.e., the low-stage methane flash gas) in conduit 160 can be routed to secondary methane economizer 74, wherein the stream can be warmed via an indirect heat exchange means 89. The resulting stream can exit secondary methane economizer 74 via conduit 162, whereafter the stream can be routed to main methane economizer 73 to be further heated via indirect heat exchange means 78. The warmed methane vapor stream can then exit main methane economizer 73 via conduit 164, whereafter the stream can be split into two portions. The first portion in conduit 164 can enter the low-stage inlet port of methane compressor 71, which will be discussed in detail shortly. The second portion in conduit 164a can be routed to an inlet port of a sales gas compressor 91. The compressed gas product exiting sales gas compressor 91 via conduit 172e can then be cooled (not shown) and routed to a location external to the LNG facility for use as a domestic gas product. Optionally, as shown in FIG. 2, at least a portion of the compressed gas stream in conduit 172e can be routed via conduit 160b to recombine with the warmed refrigerant stream in conduit 164.

As previously discussed, the warmed methane refrigerant stream in conduit 164 can enter the low-stage inlet port of methane compressor 71. Methane compressor 71 can be driven by, for example, a gas turbine driver 71a. Methane compressor 71 comprises at least one stage of compression, and, when multiple stages are employed, the stages can exist in a single unit or can be separate units mechanically coupled to a common driver. Generally, when methane compressor 71 comprises two or more compression stages, one or more intercoolers (not shown) can be provided between subsequent compression stages.

As shown in FIG. 2, the compressed methane refrigerant stream exiting methane compressor 71 can be discharged into conduit 166, whereafter the stream can be cooled via indirect heat exchange with an external fluid (e.g., air or water) in methane cooler 72. In one embodiment, the cooled compressed refrigerant stream can then be split into a compressed refrigerant fraction in conduit 112 and a domestic gas fraction in conduit 172a. Optionally, a fuel gas stream can be withdrawn from the domestic gas fraction via conduit 174a and/or from the compressed refrigerant fraction via conduit 176a. The domestic gas fraction in conduit 172a can subsequently be routed to a location outside the LNG facility, whereafter the domestic gas stream can optionally be combined with another gas stream (e.g., a portion of the feed natural gas) prior to being transported and sold to subsequent users. The fuel gas stream, if present, can be routed to one or more fuel gas consumers (e.g., gas turbine drivers 31a, 51a, and 71a of respective propane, ethylene, and methane compressors 31, 51, 71) within the LNG facility. In another embodiment, a domestic gas fraction can be withdrawn from the streams exiting the discharge of the low-stage, intermediate-stage, and/or high-stage of methane compressor 71, as indicated in FIG. 1 by respective lines 172b, 172c, 172d. In addition, optional fuel gas streams 174b-d can be withdrawn from the domestic gas fractions in corresponding conduits 172b-d or from the remaining compressed refrigerant fractions exiting the low, intermediate, and high stages of methane compressor 71 (not shown). As illustrated in FIG. 2, the compressed refrigerant fraction in conduit 112 can be further cooled in propane refrigeration cycle 30, as described in detail previously.

Upon being cooled in propane refrigeration cycle 30, the compressed methane refrigerant fraction can be discharged into conduit 130 and subsequently routed to main methane economizer 73, wherein the stream can be further cooled via indirect heat exchange means 79. The resulting sub-cooled stream exits main methane economizer 73

via conduit 168 and can then combined with the heavies-depleted stream exiting heavies removal zone 95 via conduit 126, as previously discussed.

Turning now to heavies removal zone 95, the cooled, at least partially condensed effluent exiting intermediate-stage ethylene chiller 54 via conduit 124 can be routed into the inlet of first distillation column 96, as shown in FIG. 2. A predominantly methane vapor overhead product stream can exit an upper outlet of first distillation column 96 via conduit 126. As discussed previously, the stream in conduit 126 can subsequently combine with the methane refrigerant stream in conduit 168 prior to entering low-stage ethylene chiller/condenser 55 via conduit 128. Referring back to heavies removal zone 95, a heavies-rich bottoms liquid product stream exiting a lower outlet of first distillation column 96 via conduit 170 can then be routed to an inlet of second distillation column 97. An overhead vapor product stream can exit an upper outlet of second distillation column 97 via conduit 140 prior to being combined with the warmed methane refrigerant stream in conduit 138, as discussed in detail previously. The bottoms liquid product exiting a lower outlet of second distillation column 97 can comprise the natural gas liquids (NGL) product. The NGL product, which can comprise a significant concentration of butane and heavier hydrocarbons, such as benzene, cyclohexane, and other aromatics, can be routed to further storage, processing, and/or use via conduit 171.

In one embodiment of the present invention, the LNG production systems illustrated in FIGS. 1 and 2 are simulated on a computer using conventional process simulation software in order to produce simulation results. In one embodiment, the simulation results can be in the form of a computer print out. In another embodiment, the simulation results can be displayed on a screen, monitor, or other viewing device. In yet another embodiment, the simulation results may be electronic signals directly communicated into the LNG system for direct control and/or optimization of the system.

The simulation results can then be used to manipulate the LNG system. In one embodiment, the simulation results can be used to design a new LNG facility and/or revamp or expand an existing LNG facility. In another embodiment, the simulation results can be used to optimize the LNG facility according to one or more operating parameters. In a further embodiment, the computer simulation can directly control the operation of the LNG facility by, for example, manipulating control valve output. Examples of suitable software for producing the simulation results include HYSYS™ or Aspen Plus® from Aspen Technology, Inc., and PRO/II® from Simulation Sciences Inc.

NUMERICAL RANGES

The present description uses numerical ranges to quantify certain parameters relating to the invention. It should be understood that when numerical ranges are provided, such ranges are to be construed as providing literal support for claim
5 limitations that only recite the lower value of the range as well as claims limitation that only recite the upper value of the range. For example, a disclosed numerical range of 10 to 100 provides literal support for a claim reciting "greater than 10" (with no upper bounds) and a claim reciting "less than 100" (with no lower bounds).

10 DEFINITIONS

As used herein, the terms "a," "an," "the," and "said" means one or more.

As used herein, the term "and/or," when used in a list of two or more items, means that any one of the listed items can be employed by itself, or any combination of two or more of the listed items can be employed. For example, if a composition is
15 described as containing components A, B, and/or C, the composition can contain A alone; B alone; C alone; A and B in combination; A and C in combination; B and C in combination; or A, B, and C in combination.

As used herein, the term "cascade-type refrigeration process" refers to a refrigeration process that employs a plurality of refrigeration cycles, each employing a
20 different pure component refrigerant to successively cool natural gas.

As used herein, the term "closed-loop refrigeration cycle" refers to a refrigeration cycle wherein substantially no refrigerant enters or exits the cycle during normal operation.

As used herein, the terms "comprising," "comprises," and "comprise" are open-ended transition terms used to transition from a subject recited before the term to one or
25 elements recited after the term, where the element or elements listed after the transition term are not necessarily the only elements that make up of the subject.

As used herein, the terms "containing," "contains," and "contain" have the same open-ended meaning as "comprising," "comprises," and "comprise," provided below.

30 As used herein, the term "domestic gas product" refers to any gaseous, predominantly methane stream originating from within an LNG facility that is routed to a location external to the LNG facility prior to sale and/or use.

As used herein, the terms “economizer” or “economizing heat exchanger” refer to a configuration utilizing a plurality of heat exchangers employing indirect heat exchange means to efficiently transfer heat between process streams.

As used herein, the terms “having,” “has,” and “have” have the same open-ended meaning as “comprising,” “comprises,” and “comprise,” provided above.

As used herein, the terms “heavy hydrocarbon” and “heavies” refer to any hydrocarbon component having a molecular weight greater than methane.

As used herein, the terms “including,” “includes,” and “include” have the same open-ended meaning as “comprising,” “comprises,” and “comprise,” provided above.

As used herein, the term “mid-range standard boiling point” refers to the temperature at which half of the weight of a mixture of physical components has been vaporized (i.e., boiled off) at standard pressure.

As used herein, the term “mixed refrigerant” refers to a refrigerant containing a plurality of different components, where no single component makes up more than 75 mole percent of the refrigerant.

As used herein, the term “natural gas” means a stream containing at least 85 mole percent methane, with the balance being ethane, higher hydrocarbons, nitrogen, carbon dioxide, and/or a minor amount of other contaminants such as mercury, hydrogen sulfide, and mercaptan.

As used herein, the terms “natural gas liquids” or “NGL” refer to mixtures of hydrocarbons whose components are, for example, typically heavier than ethane. Some examples of hydrocarbon components of NGL streams include propane, butane, and pentane isomers, benzene, toluene, and other aromatic compounds.

As used herein, the term “open-loop refrigeration cycle” refers to a refrigeration cycle wherein at least a portion of the refrigerant employed during normal operation originates from an external source.

As used herein, the terms “predominantly,” “primarily,” “principally,” and “in major portion,” when used to describe the presence of a particular component of a fluid stream, means that the fluid stream comprises at least 50 mole percent of the stated component. For example, a “predominantly” methane stream, a “primarily” methane stream, a stream “principally” comprised of methane, or a stream comprised “in major portion” of methane each denote a stream comprising at least 50 mole percent methane.

As used herein, the term “pure component refrigerant” means a refrigerant that is not a mixed refrigerant.

As used herein, the terms “upstream” and “downstream” refer to the relative positions of various components of a natural gas liquefaction facility along the main flow
5 path of natural gas through the plant.

CLAIMS NOT LIMITED TO DISCLOSED EMBODIMENTS

The preferred forms of the invention described above are to be used as illustration only, and should not be used in a limiting sense to interpret the scope of the present
10 invention. Modifications to the exemplary embodiments, set forth above, could be readily made by those skilled in the art without departing from the spirit of the present invention.

The inventors hereby state their intent to rely on the Doctrine of Equivalents to determine and assess the reasonably fair scope of the present invention as pertains to any
15 apparatus or process not materially departing from but outside the literal scope of the invention as set forth in the following claims.

CLAIMS

What is claimed is

1. A process for liquefying a natural gas stream in an LNG facility, said process comprising:
 - (a) cooling at least a portion of said natural gas stream in a first refrigeration cycle via indirect heat exchange with a predominantly methane refrigerant;
 - (b) flashing at least a portion of the cooled natural gas stream to thereby provide a predominantly liquid product stream and a predominantly vapor refrigerant stream;
 - (c) compressing at least a portion of said predominantly vapor refrigerant stream to thereby provide a compressed refrigerant stream; and
 - (d) separating at least a portion of said compressed refrigerant stream into a domestic gas fraction and a compressed refrigerant fraction.
2. The process of claim 1, further comprising, prior to step (a), cooling at least a portion of said natural gas stream in an upstream refrigeration cycle via indirect heat exchange with an upstream refrigerant.
3. The process of claim 2, further comprising cooling at least a portion of said compressed refrigerant fraction in said upstream refrigeration cycle.
4. The process of claim 3, wherein said upstream refrigeration cycle comprises a closed-loop refrigeration cycle.
5. The process of claim 3, wherein said upstream refrigerant comprises a pure component refrigerant.
6. The process of claim 3, wherein said upstream refrigerant comprises propane and/or ethylene.
7. The process of claim 1, further comprising, prior to step (d) and subsequent to step (c), cooling at least a portion of said compressed refrigerant stream.

8. The process of claim 1, wherein the mass flow rate of said domestic gas fraction is at least about 2 percent of the mass flow rate of said compressed refrigerant stream.

9. The process of claim 1, further comprising, optionally, withdrawing a fuel gas stream from said compressed refrigerant fraction and/or said domestic gas fraction.

10. The process of claim 1, wherein said vapor refrigerant stream provides at least a portion of said cooling of step (a).

11. The process of claim 1, further comprising producing liquefied natural gas (LNG) that comprises at least a portion of said predominantly liquid product stream.

12. The process of claim 11, wherein the produced LNG is at about atmospheric pressure.

13. The process of claim 1, further comprising routing said domestic gas fraction to a location outside of said LNG facility, wherein said routing does not require the use of a compressor other than the compressor or compressors used to carry out step (d).

14. The process of claim 1, wherein said domestic gas fraction has a pressure in the range of from about 35 to about 75 barg.

15. The process of claim 1, further comprising vaporizing LNG produced via steps (a) – (d).

16. A computer simulation process comprising utilizing a computer to simulate the process of claim 1.

17. A process for liquefying a natural gas stream in an LNG facility, said process comprising:

- (a) cooling at least a portion of said natural gas stream in an upstream refrigeration cycle of said LNG facility via indirect heat exchange with an upstream refrigerant to thereby provide a cooled natural gas stream;
- (b) further cooling at least a portion of said cooled natural gas stream via indirect heat exchange with a predominantly methane refrigerant stream in a methane refrigeration cycle to thereby produce a further cooled natural gas stream and a warmed refrigerant stream;
- (c) separating at least a portion of said warmed refrigerant stream into a domestic gas fraction and a refrigerant fraction; and
- (d) cooling at least a portion of said refrigerant fraction in said upstream refrigeration cycle via indirect heat exchange with said upstream refrigerant.

18. The process of claim 17, further comprising, prior to step (c), flashing at least a portion of said further cooled natural gas stream to thereby produce a vapor refrigerant stream and a liquid product stream.

19. The process of claim 17, further comprising, prior to step (c), compressing at least a portion of said warmed refrigerant stream, wherein said domestic gas fraction comprises at least a portion of the compressed warmed refrigerant.

20. The process of claim 19, further comprising, prior to step (c), cooling at least a portion of said compressed warmed refrigerant to thereby produce a compressed cooled refrigerant, wherein said domestic gas fraction comprises at least a portion of said compressed cooled refrigerant.

21. The process of claim 17, wherein the mass flow rate of said domestic gas fraction is at least about 2 percent of the mass flow rate of said warmed refrigerant stream.

22. The process of claim 17, further comprising, optionally, withdrawing a fuel gas stream from said refrigerant fraction and/or said domestic gas fraction.

23. The process of claim 17, wherein said upstream refrigeration cycle comprises a closed-loop refrigeration cycle.

24. The process of claim 17, wherein said methane refrigeration cycle comprises an open-loop refrigeration cycle.

25. The process of claim 17, wherein said upstream refrigerant comprises ethylene and/or ethane.

26. The process of claim 17, wherein said upstream refrigerant comprises propylene and/or propane.

27. The process of claim 17, wherein said domestic gas fraction has a pressure in the range of from about 35 to about 75 barg.

28. The process of claim 17, further comprising, vaporizing LNG produced via steps (a) – (d).

29. A computer simulation process comprising utilizing a computer to simulate the process of claim 17.

30. A process for liquefying a natural gas stream in an LNG facility, said process comprising:

- (a) cooling at least a portion of said natural gas stream in a first refrigeration cycle via indirect heat exchange with a first refrigerant to thereby produce a cooled predominantly methane stream;
- (b) separating at least a portion of said cooled predominantly methane stream in a distillation column to thereby provide a heavies-rich stream and a heavies-depleted stream;
- (c) subjecting at least a portion of said heavies-depleted stream to expansion cooling to thereby produce LNG having a pressure in the range of from about 0 to about 40 psia; and
- (d) prior to at least a portion of said expansion cooling of step (c), withdrawing a domestic gas fraction from said heavies-depleted stream.

31. The process of claim 30, wherein said expansion cooling includes flashing at least a portion of said heavies-depleted stream to thereby produce a predominantly vapor stream and a predominantly liquid stream, wherein said domestic gas fraction comprises at least a portion of said predominantly vapor stream, wherein said LNG comprises at least a portion of said predominantly liquid stream.

32. The process of claim 31, further comprising using at least a portion of said predominantly vapor stream to cool at least a portion of said heavies-depleted stream via indirect heat exchange in a second refrigeration cycle to thereby produce a warmed predominantly vapor stream, wherein said domestic gas product comprises at least a portion of said warmed predominantly vapor stream.

33. The process of claim 32, further comprising compressing at least a portion of said warmed predominantly vapor stream to thereby produce a compressed warmed predominantly vapor stream, wherein said domestic gas product comprises at least a portion of said compressed warmed predominantly vapor stream.

34. The process of claim 30, further comprising, prior to step (c), cooling at least a portion of said heavies-depleted stream in a second refrigeration cycle via indirect heat exchange with a second refrigerant.

35. The process of claim 34, wherein said second refrigeration cycle comprises an open-loop methane refrigeration cycle.

36. An LNG facility for liquefying a natural gas stream, said LNG facility comprising: an open-loop refrigeration cycle operable to cool at least a portion of said natural gas stream via indirect heat exchange with a first refrigerant, wherein said open-loop refrigeration cycle comprises -

- a first heat exchanger defining a first cooling pass and a first refrigerant pass, wherein said first heat exchanger is operable to cool at least a portion of said natural gas stream in said first cooling pass via indirect heat exchange with said first refrigerant in said first refrigerant pass;
- an expander defining an expander inlet and an expander outlet, wherein said expander inlet is coupled in fluid communication with said first cooling pass;
- a vapor-liquid separator defining a separator inlet, a lower liquid outlet, and an upper vapor outlet, wherein said separator inlet is coupled in fluid flow communication with said expander outlet, wherein said upper vapor outlet is coupled in fluid flow communication with said first refrigerant pass;
- a first refrigerant compressor defining an inlet port and an outlet port, wherein said inlet port is coupled in fluid flow communication with said first refrigerant pass;
- a compressed refrigerant conduit for routing fluid flow from said outlet port of said compressor to a location within said LNG facility; and
- a domestic gas conduit for routing fluid flow from said outlet port of said compressor and/or said compressed refrigerant conduit to a location outside said LNG facility.

37. The facility of claim 36, further comprising a closed-loop refrigeration cycle located upstream of said open-loop refrigeration cycle, wherein said closed-loop refrigeration cycle is operable to cool at least a portion of said natural gas stream via indirect heat exchange with a second refrigerant.

38. The facility of claim 36, wherein said location within said LNG facility is in said closed-loop refrigeration cycle.

39. The facility of claim 37, wherein said closed-loop refrigeration cycle is operable to cool the fluid routed thereto by said compressed refrigerant conduit via indirect heat exchange with said second refrigerant.

40. The facility of claim 37, wherein said closed-loop refrigeration cycle comprises a second heat exchanger defining a second cooling pass and a second refrigerant pass, wherein said second heat exchanger is operable to cool at least a portion of said natural gas stream in said second cooling pass via indirect heat exchange with said second refrigerant in said second refrigerant pass.

41. The facility of claim 40, wherein said second heat exchanger further comprises a third cooling pass, wherein said location inside said LNG facility is said third cooling pass, wherein said second heat exchanger is operable to cool fluid routed to said third cooling pass by said compressed refrigerant conduit via indirect heat exchange with said second refrigerant in said second refrigerant pass.

42. The facility of claim 36, wherein said LNG facility comprises a plurality of gas turbines each defining a fuel gas inlet, wherein said domestic gas conduit does not route fluid flow to any of said fuel gas inlets.

43. The facility of claim 36, further comprising at least two downstream expanders coupled in fluid communication with said expander outlet.

44. The facility of claim 43, further comprising a downstream vapor-liquid separator coupled between and in fluid flow communication with said at least two downstream expanders.

45. The facility of claim 44, wherein said first heat exchanger further comprises an additional refrigerant pass coupled in fluid flow communication with said downstream vapor-liquid separator.

46. The facility of claim 45, wherein said first refrigerant compressor further defines an additional inlet port coupled in fluid flow communication with said additional refrigerant pass.

47. The facility of claim 36, further comprising a third heat exchanger interposed in said compressed refrigerant conduit and operable to cool fluids flowing

through said compressed refrigerant conduit, wherein said domestic gas conduit is coupled in fluid flow communication with said compressed refrigerant conduit downstream of said third heat exchanger.

48. The facility of claim 36, wherein said LNG facility is a cascade-type LNG facility.

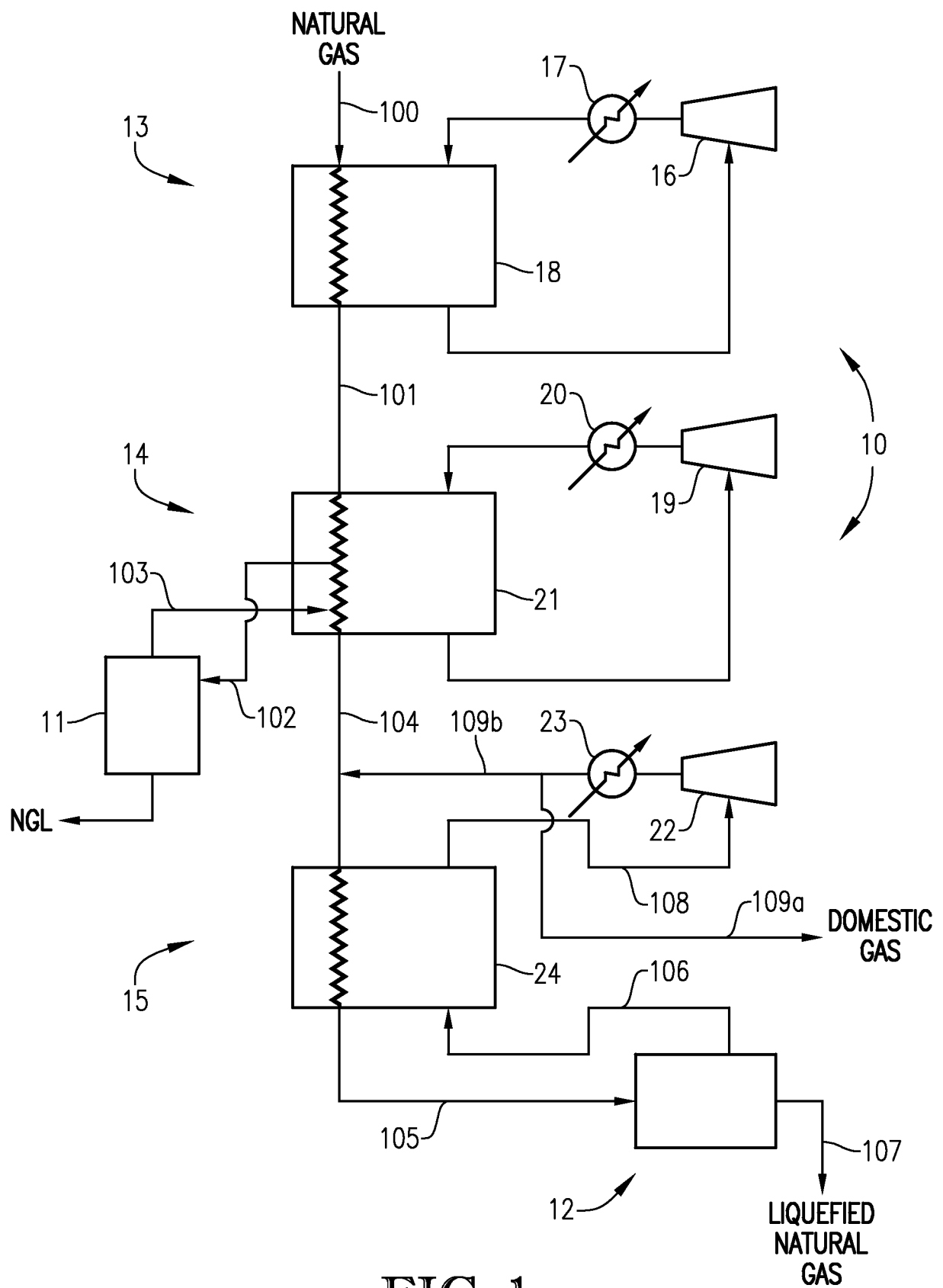


FIG. 1

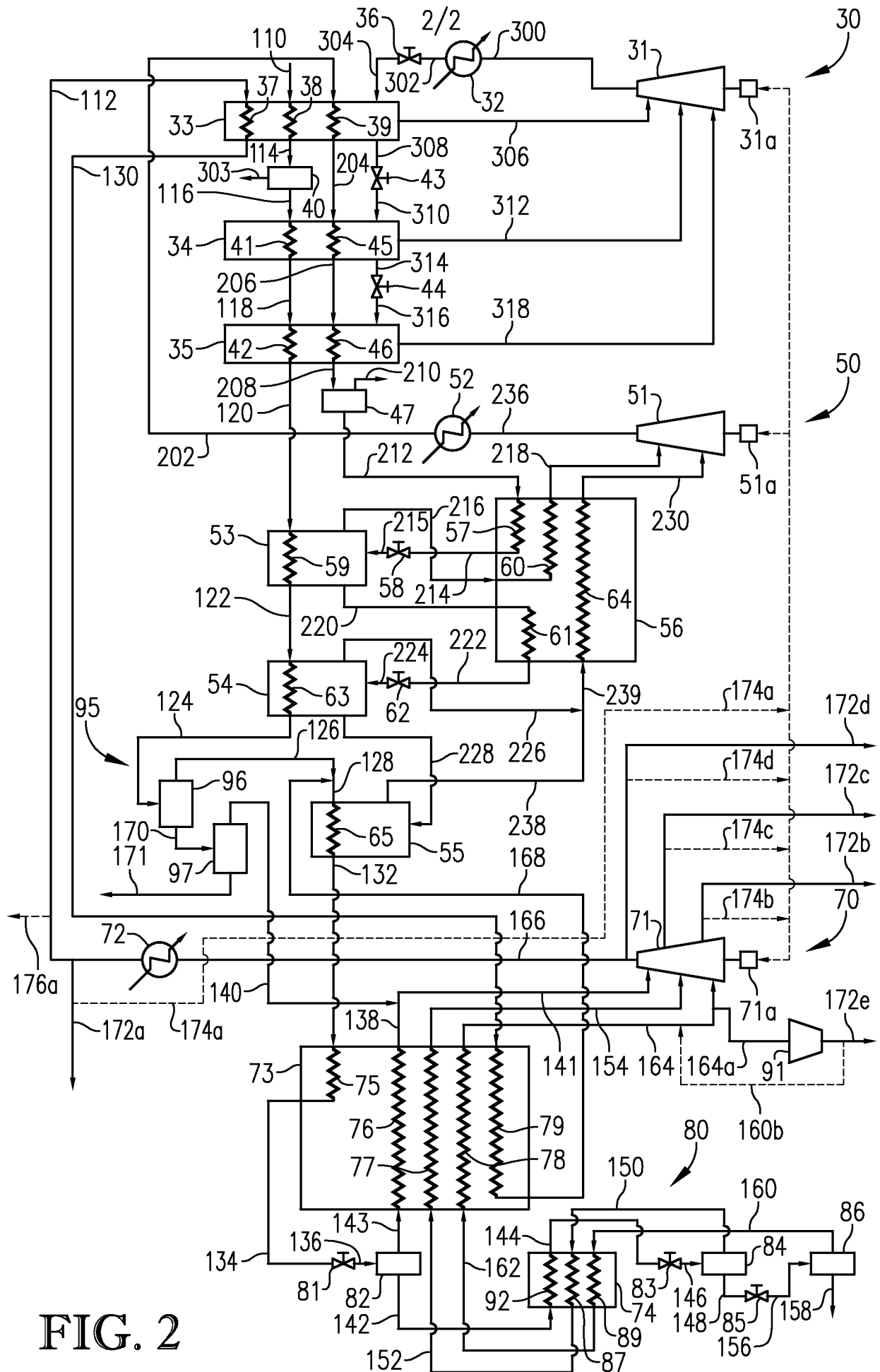


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2008/057479

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F25J 1/00 (2008.04)

USPC - 62/612

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - F25J 1/00 (2008.04)

USPC - 62/612, 611, 613, 614

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

MicroPatent, IP.com, DialogPro

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3,413,816 A (DE MARCO) 03 December 1968 (03.12.1968) entire document	1-48
Y	US 6,691,531 B1 (MARTINEZ et al) 17 February 2004 (17.02.2004) entire document	1-29
Y	US 2005/0086976 A1 (EATON) 28 April 2005 (28.04.2005) entire document	16, 29, 30-48
A	US 2007/0012071 A1 (HUANG et al) 18 January 2007 (18.01.2007) entire document	1-48

☐ Further documents are listed in the continuation of Box C.


* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search

25 July 2008

Date of mailing of the international search report

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