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Lupascu et al.

(54) CONSOLIDATED REFRIGERATION AND LIQUEFACTION MODULE IN A HYDROCARBON PROCESSING PLANT

(71) Applicants: **Sorin T. Lupascu**, Spring, TX (US); **Ashley R. Guy**, Houston, TX (US)

(72) Inventors: **Sorin T. Lupascu**, Spring, TX (US); **Ashley R. Guy**, Houston, TX (US)

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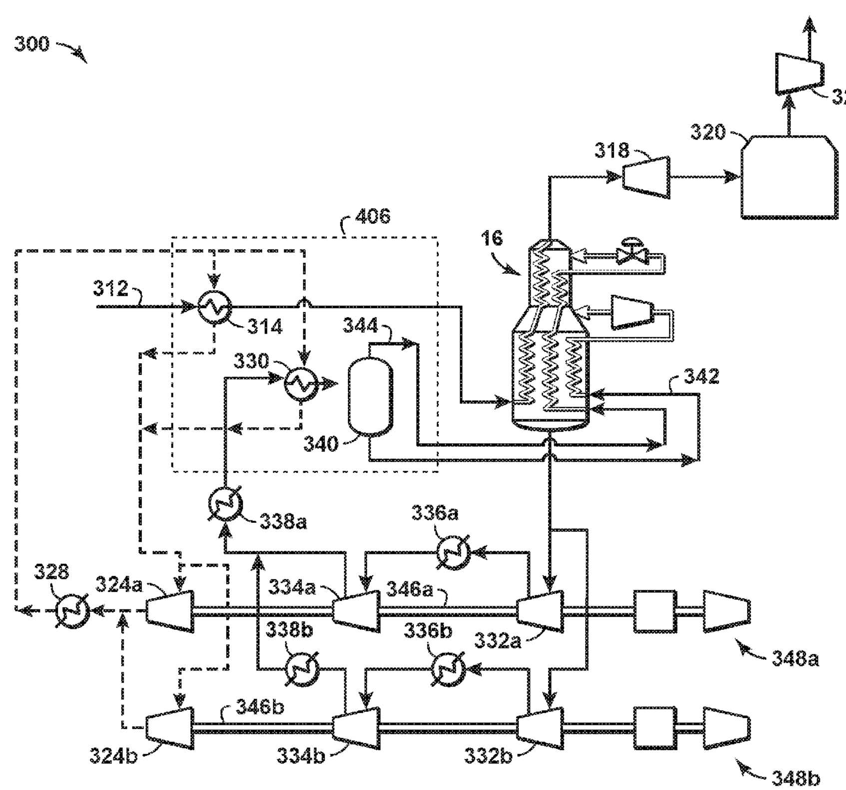
(57) **ABSTRACT**

A method of processing natural gas to produce liquefied natural gas using a consolidated refrigeration and liquefaction module. The natural gas is cooled in a first array of one or more heat exchangers using a first refrigerant from a first refrigerant circuit, wherein the first refrigerant is compressed in a first compressor. A second refrigerant from a second refrigerant circuit is compressed in a second compressor. The second refrigerant is cooled and partially condensed using the first refrigerant in a second array of one or more heat exchangers located in the consolidated refrigeration and liquefaction module. The partially condensed second refrigerant is separated into liquid and vapor phases using a refrigerant separator located in the consolidated refrigeration and liquefaction module. The natural gas is liquefied to produce LNG in a third array of one or more heat exchangers using the vapor and liquid phases of the partially condensed second refrigerant.



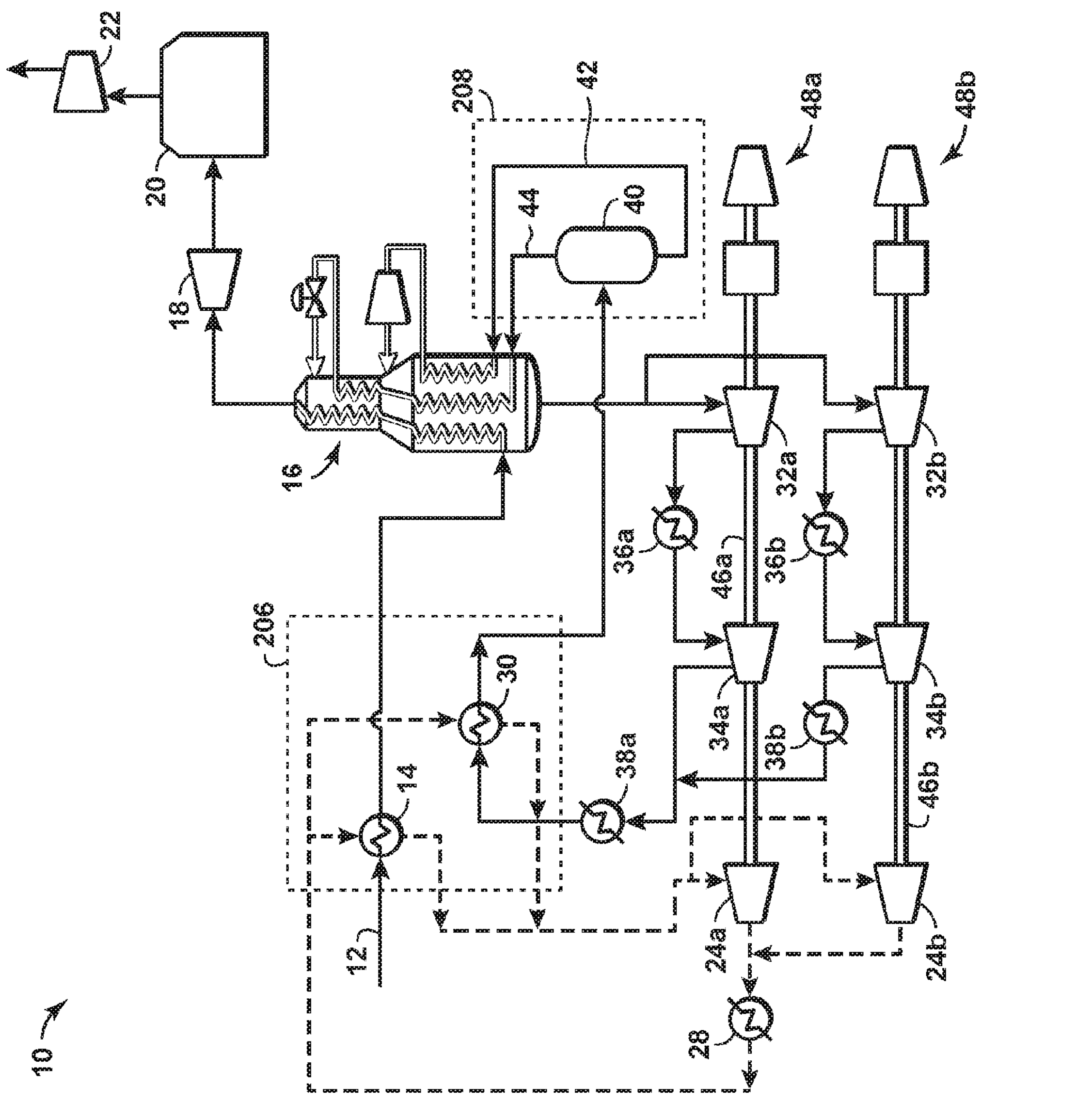


FIG. 1
Prior Art

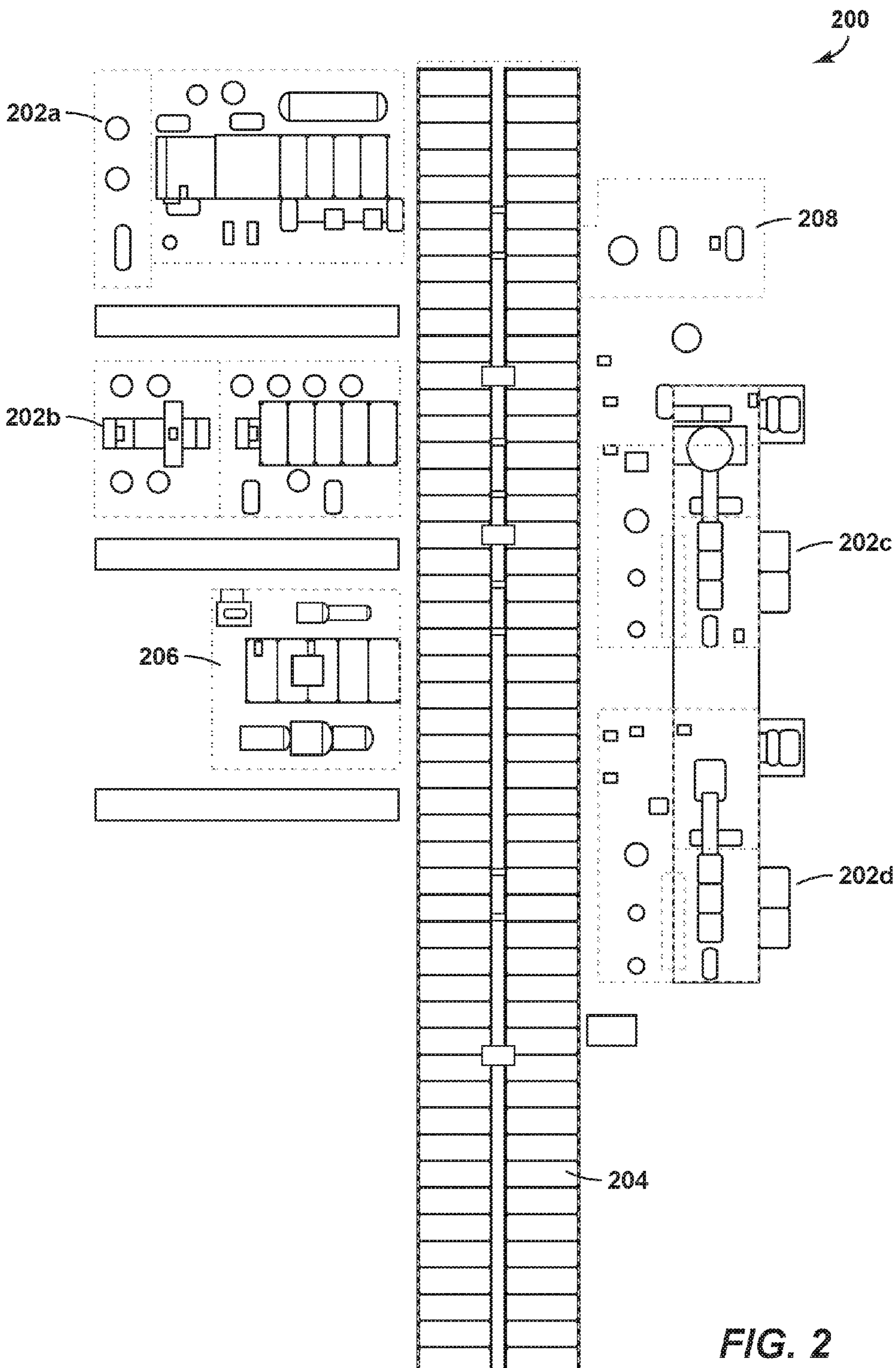


FIG. 2
Prior Art

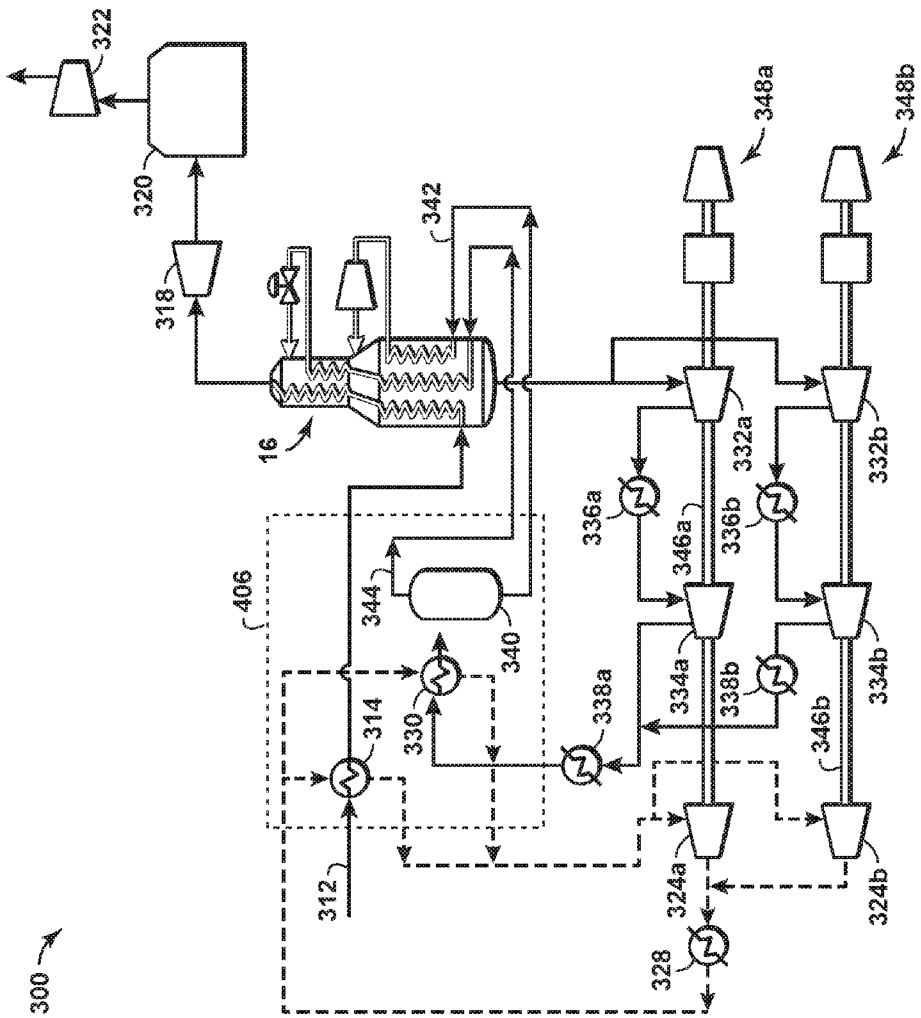

300
312
314
330
406
340
344
342
16
318
320
322
348a
348b
332a
332b
334a
334b
336a
336b
338a
338b
346a
346b
324a
324b
328

FIG. 3

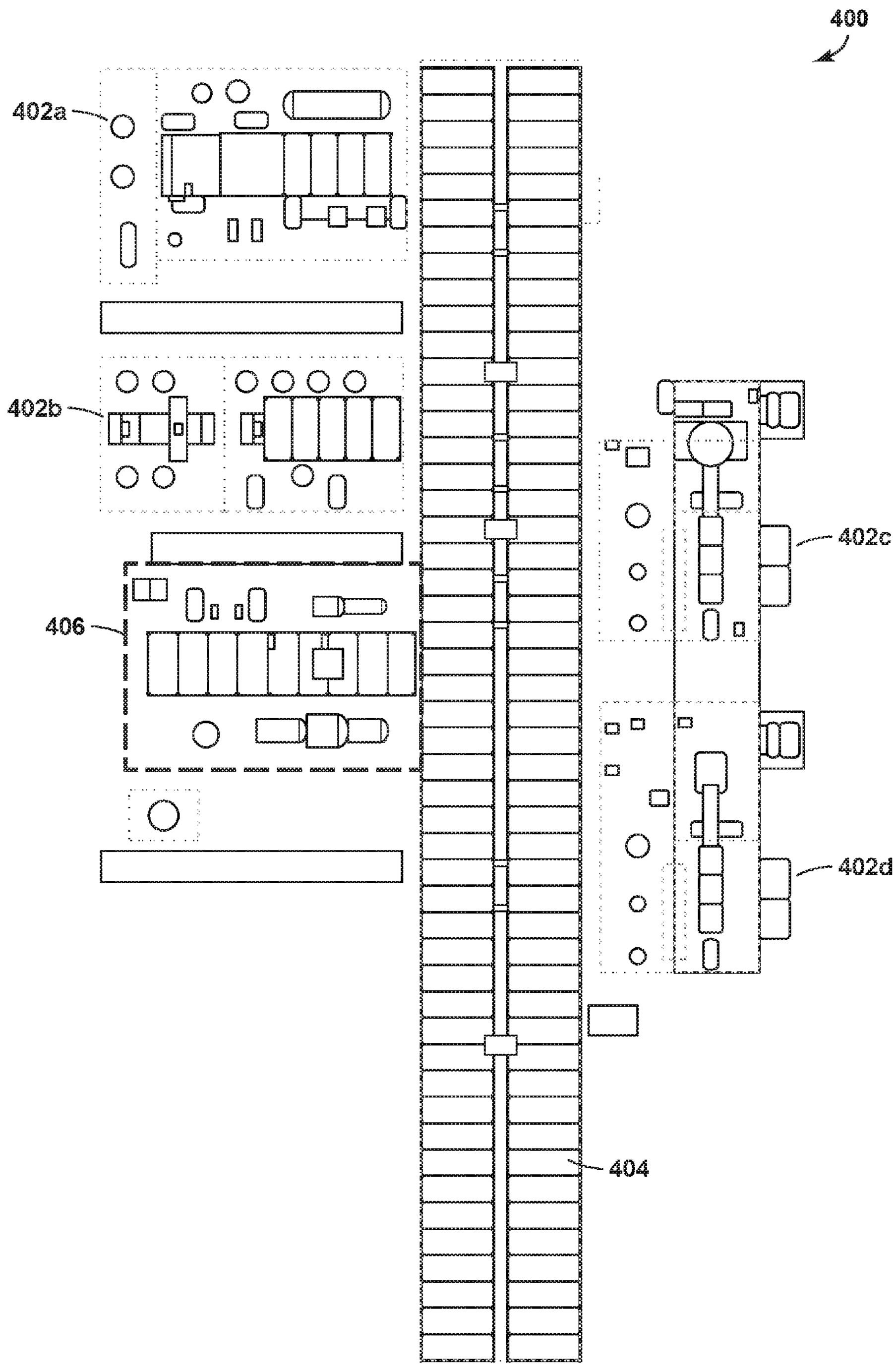


FIG. 4

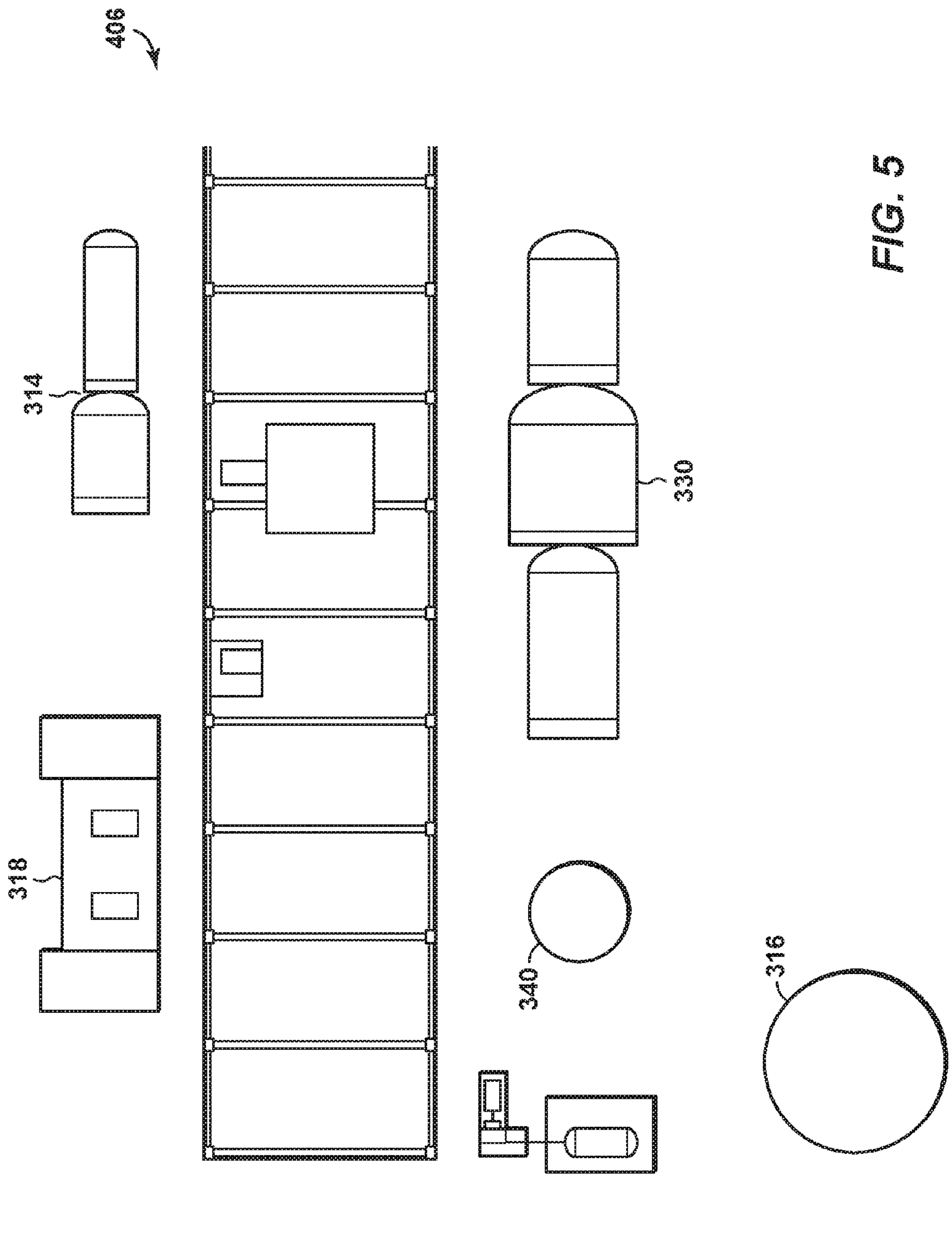


FIG. 5

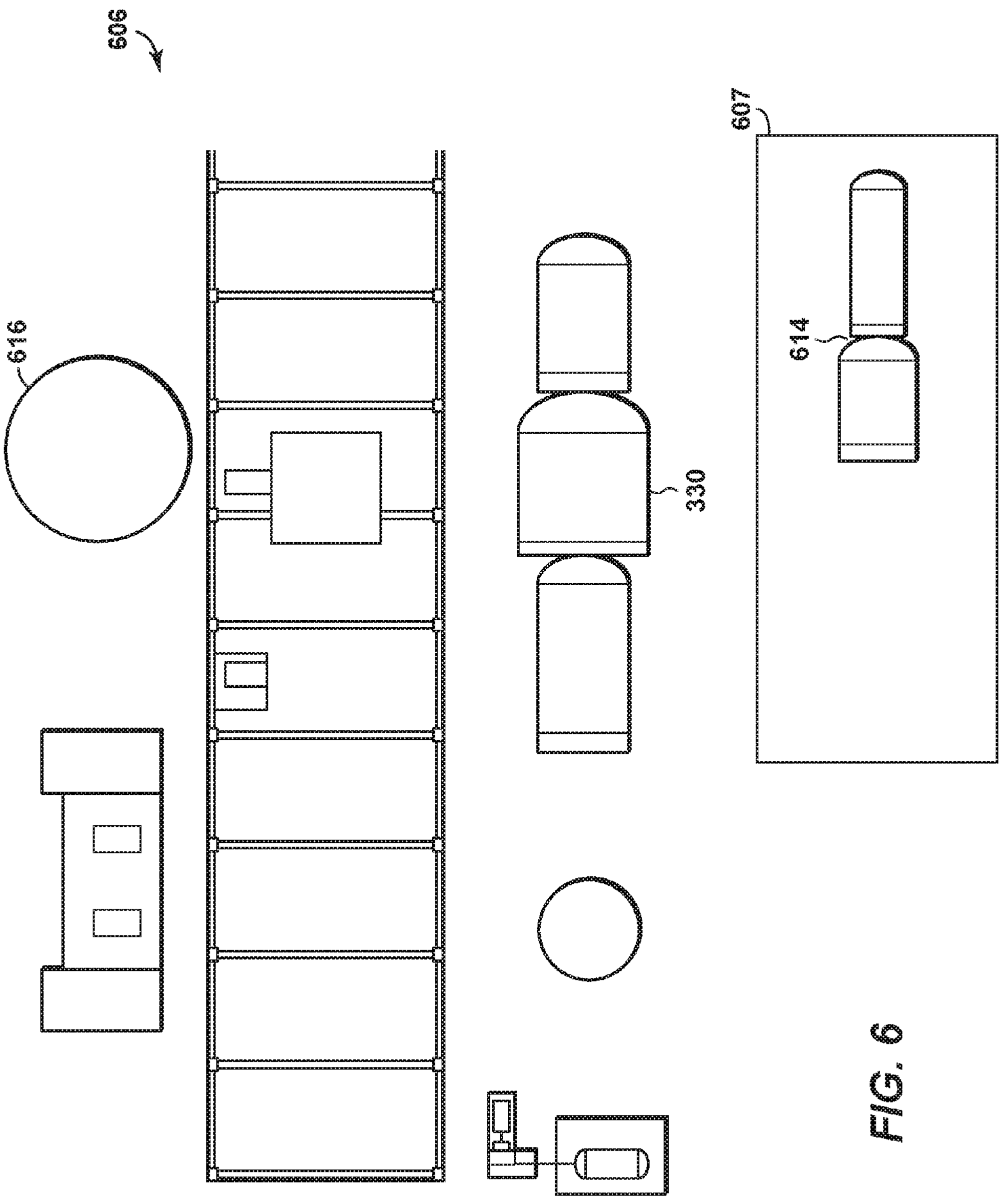


FIG. 6

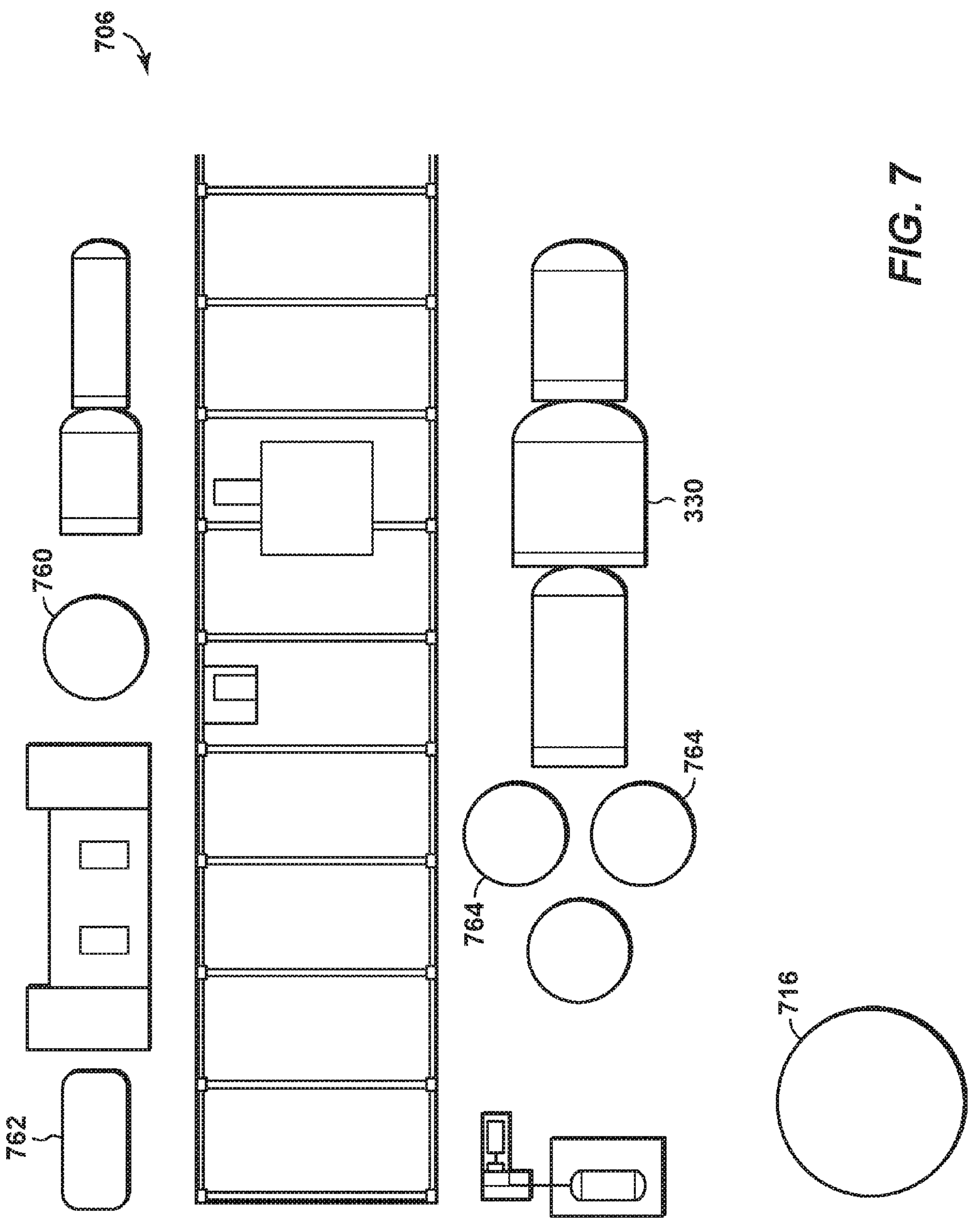


FIG. 7

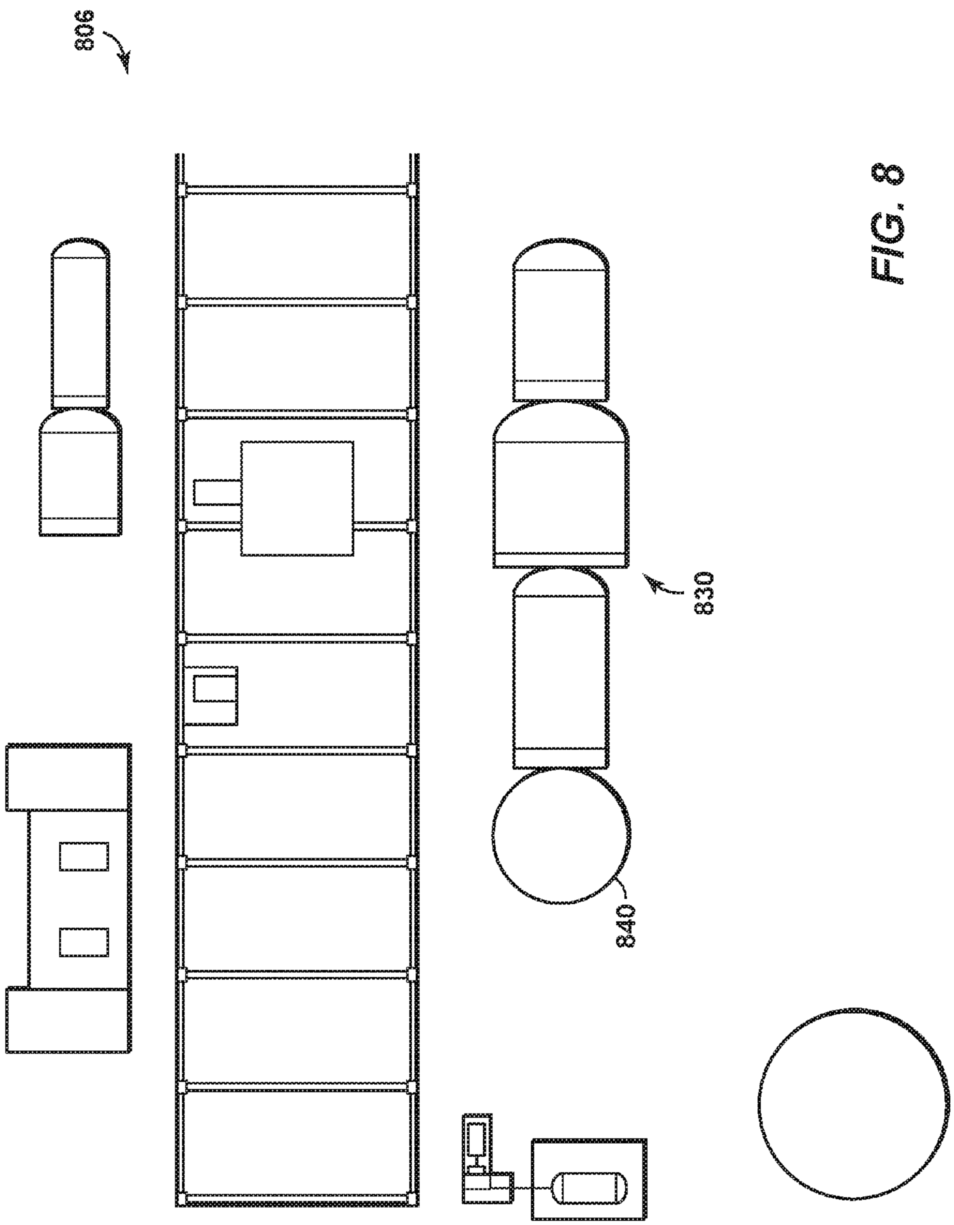


FIG. 8

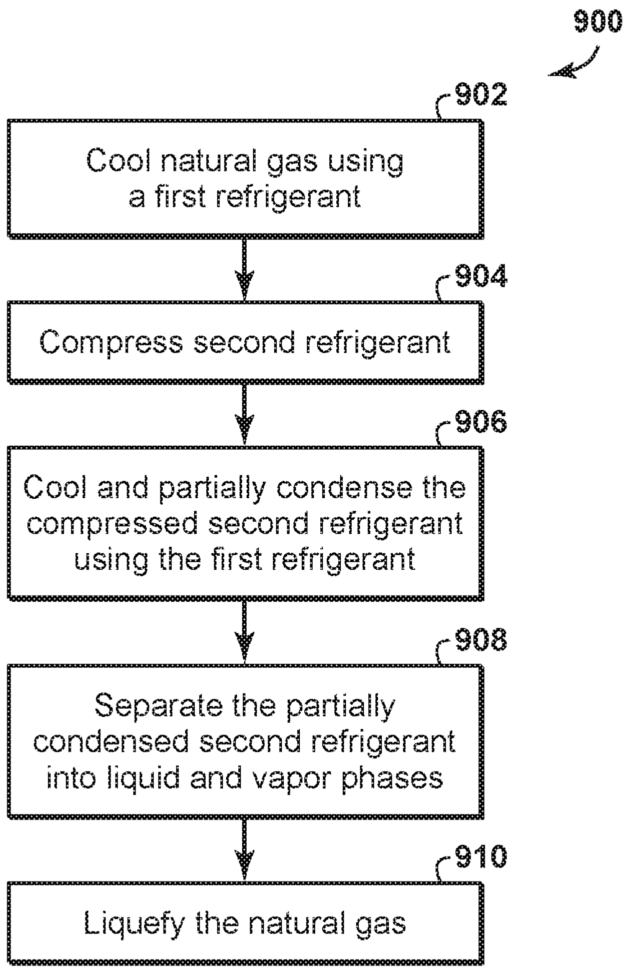

900
902
Cool natural gas using a first refrigerant
904
Compress second refrigerant
906
Cool and partially condense the compressed second refrigerant using the first refrigerant
908
Separate the partially condensed second refrigerant into liquid and vapor phases
910
Liquefy the natural gas

FIG. 9

CONSOLIDATED REFRIGERATION AND LIQUEFACTION MODULE IN A HYDROCARBON PROCESSING PLANT

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Patent Application Nos. 62/237,842 filed Oct. 6, 2015 entitled CONSOLIDATED REFRIGERATION AND LIQUEFACTION MODULE IN A HYDROCARBON PROCESSING PLANT, the entirety of each which is incorporated by reference herein.

BACKGROUND

[0002] Field of Disclosure

[0003] The disclosure relates generally to the field of hydrocarbon handling and processing plants. More specifically, the disclosure relates to the efficient construction and operation of hydrocarbon handling and processing plants, such as LNG processing plants.

[0004] Description of Related Art

[0005] This section is intended to introduce various aspects of the art, which may be associated with the present disclosure. This discussion is intended to provide a framework to facilitate a better understanding of particular aspects of the present disclosure. Accordingly, it should be understood that this section should be read in this light, and not necessarily as admissions of prior art.

[0006] In a time when competition for LNG production contracts is increasing, there is a tremendous need to enhance the profitability of future LNG projects. To do so, LNG producers may identify and optimize the key cost drivers and efficiencies applicable to each project. Rendering projects economical in locations with high costs and low on-site labor productivity may require minimizing the scope and extent of site labor required to construct and commission the LNG plant. Modularization techniques are being employed to tackle this challenge by shifting scope from being built on-site to being built in specialized fabrication yards. However, for large scale LNG projects the modularization of construction scope can still result in significant site integration costs. Previous modularization solutions have involved dividing as much of the LNG plant as possible into modules, pre-fabricating the modules at a manufacturing site, and transporting the modules to an operating site, where the modules are connected to form the LNG plant. Such a solution may require substantial labor at the operating site, which may make financial sense when labor costs at the operating site are low. For operating sites where labor costs are high, however, such a solution may increase the labor costs above that which makes the LNG plant unaffordable to construct. Accordingly, there is a recognized need in the plant construction industry to remove additional work scope from the operating site compared to other modularization methods currently deployed by industry.

[0007] FIG. **1** is a schematic diagram of an LNG producing facility **10** according to known principles. Feed gas in a feed gas line **12** is pre-cooled in a first chiller **14** using a first refrigerant such as propane. The feed gas is then cooled and liquefied in a main cryogenic heat exchanger **16** using a mixed refrigerant. The liquefied natural gas is expanded in a hydraulic turbine **18** or similar expansion device and is stored in an LNG storage tank **20**. A boil-off gas compressor **22** compresses the liquefied natural gas prior to it being transported from the LNG storage tank **20**.

[0008] The first refrigerant and the mixed refrigerant cycle through separate refrigerant loops. The first refrigerant loop is compressed in one or more compressors **24***a*, **24***b* and further processed in (a) a desuperheater, which cools the hot vapor to a saturated vapor, (b) a condenser that condenses the saturated vapor to liquid form, and (c) cooled in a sub-cooler. Functions (a)-(c) are represented in FIG. **1** by cooler element **28**. The cooled and liquefied first refrigerant at this point is substantially in liquid form. A first part of the liquefied first refrigerant is directed to the first chiller **14**, where as previously discussed the first refrigerant pre-cools the feed gas in feed gas line **12**. A second part of the liquefied first refrigerant is directed to a second chiller **30** where the first refrigerant pre-chills the mixed refrigerant. The first refrigerant, now in substantially vapor form, is directed from the first chiller **14** and the second chiller **30** to the compressors **24***a*, **24***b*, and the first refrigerant loop repeats.

[0009] In the mixed refrigerant loop, the mixed refrigerant leaving the main cryogenic heat exchanger **16** is in a vapor state, and is compressed and cooled in a series of compressors **32***a*, **32***b*, **34***a*, **34***b*, and inter-stage coolers and discharge coolers **36***a*, **36***b*, **38***a*, **38***b*. Mixed refrigerant exiting the discharge chillers **38***a*, **38***b* is directed to the second chiller **30**, where it is further cooled by the second part of the first refrigerant. The mixed refrigerant then is directed to a mixed refrigerant separator **40** that separates and outputs the mixed refrigerant liquid stream (in line **42**) and the mixed refrigerant vapor stream (in line **44**). Both lines **42** and **44** are connected to the main cryogenic heat exchanger **16**, where the mixed refrigerant cools and liquefies the chilled feed gas directed from the first chiller **14**. The mixed refrigerant exiting the main cryogenic heat exchanger **16** is substantially in a vapor state and is directed to the compressors **32***a*, **32***b* to continue the mixed refrigerant loop. In the LNG producing facility **10**, the compressors **24***a*, **32***a*, and **34***a* are connected to a common shaft **46***a* and powered by a turbine assembly **48***a*. Likewise, the compressors **24***b*, **32***b*, and **34***b* are connected to a common shaft **46***b* and powered by a turbine assembly **48***b*. Other compressor and driver configurations can be deployed as is known to those familiar with the art.

[0010] FIG. **2** depicts a known layout of an LNG producing facility **200**, which may be termed an LNG train. The LNG train **200** includes multiple processing modules **202***a*, **202***b*, **202***c*, **202***d* disposed along a central piperack **204**. The processing modules **202***a-d* are connected to each other and to any functional units within the piperack via multiple pipes and conduits that direct utility streams, feed gas and resulting products and side-prodcuts as desired. The processing modules may include: an acid gas removal unit that removes CO_2 and H_2S molecules from the feed gas down to the very low levels required to prevent freezing in the downstream refrigeration and liquefaction units; a dehydration unit that removes water molecules from the feed gas down to the very low levels required to prevent freezing in the downstream refrigeration and liquefaction units; a heavy hydrocarbon capture (HHC) or heavy hydrocarbon removal unit that removes C_6^+ molecules from the feed gas below levels necessary to prevent freezing in the downstream refrigeration and liquefaction units, and the like. Additionally, a refrigeration processing module **206** includes the one or more feed gas propane chillers **14** and the one or more mixed refrigerant chillers **30**, as disclosed in FIG. **1**. A liquefaction processing module **208** includes the mixed refrigerant separator **40** as well as lines **42** and **44** that connect to the main cryogenic heat exchanger **16**, which may be located adjacent the liquefaction processing module **208**. Each of the processing modules may be pre-assembled at a fabrication yard or other off-site manufacturing location, transported to the operating site of the LNG train, and connected together to construct the completed LNG train.

[0011] The LNG train **200** shown in FIG. **2** represents known attempts to modularize gas processing plant design, and is characterized by installing the process modules along the central piperack **204**, and piping connections between separate process modules are routed through the central piperack **204**. The central piperack may be formed by piperack segments or modules that are built at a manufacturing site, transported to an operating site, and assembled together at the operating site. However, this modularization strategy results in a significant number of piping connections at the interfaces between the process modules and the central piperack.

[0012] Connecting the piping connections onsite is a labor-intensive activity. Furthermore, every line connecting two process modules, such as the refrigeration processing module **206** and the liquefaction processing module **208**, must pass through the central piperack to do so, and there will be a minimum of two site connections at interfaces with each central piperack segment the line must pass through. As there may be significant connections between the refrigeration processing module **206** and the liquefaction processing module **208**, connecting these two modules at the operating site may incur significant time and expense. What is needed is a hydrocarbon processing plant design that minimizes such assembly costs.

SUMMARY

[0013] The present disclosure provides a method of processing natural gas to produce liquefied natural gas (LNG) using a consolidated refrigeration and liquefaction module. The natural gas is cooled in a first array of one or more heat exchangers using a first refrigerant from a first refrigerant circuit, wherein the first refrigerant is compressed in a first compressor.

[0014] A second refrigerant from a second refrigerant circuit is compressed in a second compressor. The compressed second refrigerant is cooled and partially condensed using the first refrigerant in a second array of one or more heat exchangers located in the consolidated refrigeration and liquefaction module. The partially condensed second refrigerant is separated into liquid and vapor phases using a refrigerant separator located in the consolidated refrigeration and liquefaction module. The natural gas to produce LNG in a third array of one or more heat exchangers using the vapor and liquid phases of the partially condensed second refrigerant.

[0015] The present disclosure also provides a hydrocarbon processing plant, comprising: a first refrigerant circuit; a first refrigerant configured to circulate in the first refrigerant circuit; a first compressor configured to compress the first refrigerant; a first array of one or more heat exchangers configured to cool a hydrocarbon stream using the first refrigerant; a second refrigerant circuit; a second refrigerant configured to circulate in the second refrigerant circuit; a second compressor configured to compress the second refrigerant; a second array of one or more heat exchangers configured to cool and partially condense the compressed second refrigerant using the first refrigerant; a refrigerant separator configured to separate the partially condensed second refrigerant into liquid and vapor phases; a third array of one or more heat exchangers configured to liquefy the hydrocarbon stream using the vapor and liquid phases of the partially condensed second refrigerant; and a consolidated refrigeration and liquefaction module within which is located the second array of one or more heat exchangers and the refrigerant separator.

[0016] The foregoing has broadly outlined the features of the present disclosure so that the detailed description that follows may be better understood. Additional features will also be described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] These and other features, aspects and advantages of the disclosure will become apparent from the following description, appending claims and the accompanying drawings, which are briefly described below.

[0018] FIG. **1** is a schematic diagram of an LNG liquefaction process according to known principles.

[0019] FIG. **2** is a top plan view of an LNG train according to known principles.

[0020] FIG. **3** is a schematic diagram of an LNG liquefaction process according to disclosed aspects.

[0021] FIG. **4** is a top plan view of an LNG train according to disclosed aspects.

[0022] FIG. **5** is a top plan view of a consolidated refrigeration and liquefaction module according to disclosed aspects.

[0023] FIG. **6** is a top plan view of a consolidated refrigeration and liquefaction module according to disclosed aspects.

[0024] FIG. **7** is a top plan view of a consolidated refrigeration and liquefaction module according to disclosed aspects.

[0025] FIG. **8** is a top plan view of a consolidated refrigeration and liquefaction module according to disclosed aspects.

[0026] FIG. **9** is a method of designing an LNG train according to known principles.

[0027] It should be noted that the figures are merely examples and no limitations on the scope of the present disclosure are intended thereby. Further, the figures are generally not drawn to scale, but are drafted for purposes of convenience and clarity in illustrating various aspects of the disclosure.

DETAILED DESCRIPTION

[0028] For the purpose of promoting an understanding of the principles of the disclosure, reference will now be made to the features illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the disclosure is thereby intended. Any alterations and further modifications, and any further applications of the principles of the disclosure as described herein are contemplated as would normally occur to one skilled in the art to which the disclosure relates. It will be apparent to those skilled in the relevant art that some features that are not relevant to the present disclosure may not be shown in the drawings for the sake of clarity.

[0029] At the outset, for ease of reference, certain terms used in this application and their meanings as used in this context are set forth. To the extent a term used herein is not defined below, it should be given the broadest definition persons in the pertinent art have given that term as reflected in at least one printed publication or issued patent. Further, the present techniques are not limited by the usage of the terms shown below, as all equivalents, synonyms, new developments, and terms or techniques that serve the same or a similar purpose are considered to be within the scope of the present claims.

[0030] As one of ordinary skill would appreciate, different persons may refer to the same feature or component by different names. This document does not intend to distinguish between components or features that differ in name only. The figures are not necessarily to scale. Certain features and components herein may be shown exaggerated in scale or in schematic form and some details of conventional elements may not be shown in the interest of clarity and conciseness. When referring to the figures described herein, the same reference numerals may be referenced in multiple figures for the sake of simplicity. In the following description and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus, should be interpreted to mean "including, but not limited to."

[0031] The articles "the," "a" and "an" are not necessarily limited to mean only one, but rather are inclusive and open ended so as to include, optionally, multiple such elements.

[0032] The term "acid gas" and "sour gas" refers to any gas that dissolves in water to produce an acidic solution. Non-limiting examples of acid gases include hydrogen sulfide (H_2S), carbon dioxide (CO_2), or sulfur dioxide (SO_2), or mixtures thereof

[0033] As used herein, the terms "approximately," "about," "substantially," and similar terms are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. It should be understood by those of skill in the art who review this disclosure that these terms are intended to allow a description of certain features described and claimed without restricting the scope of these features to the precise numeral ranges provided. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and are considered to be within the scope of the disclosure.

[0034] The term "heat exchanger" refers to a device designed to efficiently transfer or "exchange" heat from one matter to another. Exemplary heat exchanger types include a co-current or counter-current heat exchanger, an indirect heat exchanger (e.g. spiral wound heat exchanger, plate-fin heat exchanger such as a brazed aluminum plate fin type, shell-and-tube heat exchanger, etc.), direct contact heat exchanger, or some combination of these, and so on.

[0035] Although the phrases "gas stream," "vapor stream," and "liquid stream," refer to situations where a gas, vapor, and liquid is mainly present in the stream, respectively, there may be other phases also present within the stream. For example, a gas may also be present in a "liquid stream." In some instances, the terms "gas stream" and "vapor stream" may be used interchangeably.

[0036] The disclosure relates to a system and method for the standardized design and construction of a hydrocarbon handling and processing plant, such as an LNG train. In an aspect, a significant number of connections between modules and/or processing units may be eliminated by locating many or all of the components relating to refrigeration and liquefaction of natural gas in a single processing module. The consolidated refrigeration and liquefaction module may be completely or substantially constructed at a manufacturing site that is separate from an operating site of the hydrocarbon handling and processing plant, and then transported to the operating site, where the consolidated refrigeration and liquefaction module is connected to the remainder of the hydrocarbon handling and processing plant. In an aspect, at least part of the remainder of the hydrocarbon handling and processing plant is made of modules that are also assembled or manufactured at a manufacturing site, transported to the operating site, and assembled at the operating site to form the hydrocarbon handling and processing plant. The consolidated refrigeration and liquefaction module may be connected to one or more of the modules of the remainder of the hydrocarbon handling and processing plant.

[0037] FIGS. **3**-**5** of the disclosure display various aspects of the system and method in comparison with known LNG plant layouts. FIG. **3** is a schematic diagram of an LNG producing facility **300** according to known principles. Feed gas in a feed gas line **312** is pre-cooled in a first chiller **314** using a first refrigerant such as propane. The feed gas is then cooled and liquefied in a main cryogenic heat exchanger **316** using a mixed refrigerant. The liquefied natural gas is expanded in a hydraulic turbine **318** or similar expansion device and is stored in an LNG storage tank **320**. A boil-off gas compressor **322** compresses the liquefied natural gas leaving/exiting the LNG storage tank **320**.

[0038] The first refrigerant and the mixed refrigerant cycle through separate refrigerant loops. The first refrigerant loop is compressed in one or more compressors **324***a*, **324***b* and further processed in (a) a desuperheater, which cools the hot vapor to a saturated vapor, (b) a condenser that condenses the saturated vapor to liquid form, and (c) cooled in a sub-cooler. Functions (a)-(c) are represented in FIG. **3** by cooler element **328**. The cooled and liquefied first refrigerant at this point is substantially in liquid form. A first part of the liquefied first refrigerant is directed to the first chiller **314**, where as previously discussed the first refrigerant pre-cools the feed gas in feed gas line **312**. A second part of the liquefied first refrigerant is directed to a second chiller **330** where the first refrigerant pre-chills the mixed refrigerant. The first refrigerant, now in substantially vapor form, is directed from the first chiller **314** and the second chiller **330** to the compressors **324***a*, **324***b*, and the first refrigerant loop repeats.

[0039] In the mixed refrigerant loop, the mixed refrigerant leaving the main cryogenic heat exchanger **316** is in a vapor and/or liquid state, and is compressed and cooled in a series of compressors **332***a*, **332***b*, **334***a*, **334***b*, and inter-stage and discharge coolers **336***a*, **336***b*, **338***a*, **338***b*. Mixed refrigerant exiting the chillers **338***a*, **338***b* is directed to the second chiller **330**, where it is further cooled by the second part of the first refrigerant. The mixed refrigerant then is directed to a mixed refrigerant separator **340** that separates and outputs the mixed refrigerant liquid stream (in line **342**) and the mixed refrigerant vapor stream (in line **344**). Both lines **342**

and **344** are connected to the main cryogenic heat exchanger **316**, where the mixed refrigerant cools and liquefies the chilled feed gas directed from the first chiller **314**. The mixed refrigerant exiting the main cryogenic heat exchanger **316** is substantially in a vapor state and is directed to the compressors **332***a*, **332***b* to continue the mixed refrigerant loop. In the LNG producing facility **310**, the compressors **324***a*, **332***a*, and **334***a* are connected to a common shaft **346***a* and powered by a turbine assembly **348***a*. Likewise, the compressors **324***b*, **332***b*, and **334***b* are connected to a common shaft **346***b* and powered by a turbine assembly **348***b*. Other compressor and driver configurations can be deployed as is known to those familiar with the art.

[0040] FIG. **4** depicts a layout of an LNG producing facility **400**, which may be termed an LNG train, according to disclosed aspects. The LNG train **400** includes multiple processing modules **402***a*, **402***b*, **402***c*, **402***d* disposed along a central piperack **404**. Each of the processing modules may be pre-assembled at a fabrication yard or other off-site location, transported to the site of the LNG train, and connected together to construct the completed LNG train. The processing modules **402***a-d* are connected to each other and to any functional units within the piperack via multiple pipes and conduits that direct feed gas and resulting products and side-prodcuts as desired. The processing modules may include: an acid gas removal unit that removes CO_2 and H_2S molecules from the feed gas down to the very low levels required to prevent freezing in the downstream refrigeration and liquefaction units; a dehydration unit that removes water molecules from the feed gas down to the very low levels required to prevent freezing in the downstream refrigeration and liquefaction units; a heavy hydrocarbon capture (HHC) or heavy hydrocarbon removal unit that removes C_6^+ molecules from the feed gas below levels necessary to prevent freezing in the downstream refrigeration and liquefaction units, and the like.

[0041] In one aspect, a consolidated refrigeration and liquefaction module **406** includes the one or more feed gas propane chillers **314** and the one or more mixed refrigerant chillers **330**. The consolidated refrigeration and liquefaction module **406** also includes the mixed refrigerant separator **340** as well as lines **344** and **342** that connect to the main cryogenic heat exchanger **316**, which may be located on or adjacent the consolidated refrigeration and liquefaction module **406**. An additional array of cooling elements, such as fin fan coolers, may be co-located with the feed gas propane chillers **314**, the mixed refrigerant chillers **330**, and/or the main cryogenic heat exchanger **316**. Additionally, all piping, valving, instrumentation, and auxiliary components associated with the feed gas propane chillers **314**, mixed refrigerant chillers **330**, the mixed refrigerant separator **340**, and/or the main cryogenic heat exchanger **316** and/or other items may be situated on or within the consolidated refrigeration and liquefaction module **406**. Further, the consolidated refrigeration and liquefaction module **406** may include one or more hydraulic turbines **318** for isentropic expansion of the LNG, and/or one or more hydraulic turbines for isentropic expansion of the mixed refrigerant. The arrangement shown in FIGS. **4-5** eliminates labor-intensive piping connections previously required to be performed at the operating site to connect the feed gas propane chillers **14** to the main cryogenic heat exchanger **16** through the central piperack **202**. Instead, chilled feed gas exiting the feed gas propane chiller **314** is directly connected to the main cryogenic heat exchanger **316**, which is on or adjacent the consolidated refrigeration and liquefaction module **406**. This arrangement also eliminates piping connections required to be made at the operating site to connect the mixed refrigerant propane chillers **30** to the mixed refrigerant separator **40** through the central piperack **202**. Instead, mixed refrigerant exiting the mixed refrigerant propane chillers **330** is connected directly to the high pressure mixed refrigerant separator **340** that is co-located with the mixed refrigerant propane chillers **30** on the consolidated refrigeration and liquefaction module **406**.

[0042] FIGS. **6-8** depict additional aspects of the disclosure, showing various alternative arrangements for the consolidated refrigeration and liquefaction module. FIG. **6** shows a consolidated refrigeration and liquefaction module **606** in which the feed gas propane chillers **614** are mounted on a separate module **607**. This aspect still results in fewer connections required to be made at the operating site as compared with known arrangements, although this aspect is less efficient than the arrangement disclosed in FIGS. **4-5**. FIG. **6** also shows how the main cryogenic heat exchanger **616** may be attached to the consolidated refrigeration and liquefaction module **606**. Such attachment may occur at the operating site or at a manufacturing site separate from the operating site. FIG. **7** shows additional components of the LNG train which may be included on a consolidated refrigeration and liquefaction module **706**. A scrub column **760** may be installed to remove heavy hydrocarbon components from the feed gas prior to liquefaction in the main cryogenic heat exchanger **716**. A propane accumulator **762** may be installed to be used as a buffer storage for the condensed propane refrigerant. A propane subcooler heat exchanger **764**, which may perform one or more functions represented by cooler element **330**, may also be installed on the consolidated refrigeration and liquefaction module **706**. Some or all of these additional components may be included thereon in any combination. Furthermore, the arrangement of components, including these additional components, on the consolidated refrigeration and liquefaction module may be done to minimize the amount of piping between components thereon, and the arrangement of components as depicted in the Figures is only an example of such arrangements. FIG. **8** depicts a consolidated refrigeration and liquefaction module **806** in which the mixed refrigerant separator **840** is integral with or closely connected to the mixed refrigerant chillers **830**. In an aspect, the length of piping connecting the mixed refrigerant chillers **830** and the mixed refrigerant separator **840** is less than ten meters. Integrating or co-locating the mixed refrigerant chillers **830** and the mixed refrigerant separator **840** as described herein provides substantial cost savings and reduction in

[0043] LNG plant design when compared to known LNG plant designs, where these two components typically are located in separate modules and even on opposite sides of the central piperack.

[0044] An advantage of the disclosed aspects is a decrease in the number of connections required to be made at the operating site, a decrease in the overall number of process modules, and the cost savings associated therewith. Additional benefits are realized by schedule and logistics synergies associated with the reconfigured layout shown in FIGS. **4-8** and the opportunity to conduct more pre-commissioning of the refrigeration and liquefaction process systems at a manufacturing site rather than at the operating site.

[0045] FIG. 9 depicts a method 900 of processing natural gas to produce liquefied natural gas (LNG) using a consolidated refrigeration and liquefaction module according to disclosed aspects. In step 902 the natural gas is cooled in a first array of one or more heat exchangers using a first refrigerant from a first refrigerant circuit, wherein the first refrigerant is compressed in a first compressor. In step 904 a second refrigerant from a second refrigerant circuit is compressed in a second compressor. In step 906 the compressed second refrigerant is cooled and partially condensed using the first refrigerant in a second array of one or more heat exchangers located in the consolidated refrigeration and liquefaction module. In step 908 the partially condensed second refrigerant is separated into liquid and vapor phases using a refrigerant separator located in the consolidated refrigeration and liquefaction module. In step 910 the natural gas is liquefied to produce LNG in a third array of one or more heat exchangers using the vapor and liquid phases of the partially condensed second refrigerant.

[0046] The steps depicted in FIG. 9 are provided for illustrative purposes only and a particular step may not be required to perform the inventive methodology. Moreover, FIG. 9 may not illustrate all the steps that may be performed. The claims, and only the claims, define the inventive system and methodology.

[0047] Disclosed aspects may be used in hydrocarbon management activities. As used herein, "hydrocarbon management" or "managing hydrocarbons"" includes hydrocarbon extraction, hydrocarbon production, hydrocarbon exploration, identifying potential hydrocarbon resources, identifying well locations, determining well injection and/or extraction rates, identifying reservoir connectivity, acquiring, disposing of and/ or abandoning hydrocarbon resources, reviewing prior hydrocarbon management decisions, and any other hydrocarbon-related acts or activities. The term "hydrocarbon management" is also used for the injection or storage of hydrocarbons or CO_2, for example the sequestration of CO_2, such as reservoir evaluation, development planning, and reservoir management. The disclosed methodologies and techniques may be used in extracting hydrocarbons from a subsurface region and/or processing the hydrocarbons. Hydrocarbons and contaminants may be extracted from a reservoir and processed. The hydrocarbons and contaminants may be processed, for example, in the LNG plant as described herein. Other hydrocarbon extraction activities and, more generally, other hydrocarbon management activities, may be performed according to known principles.

[0048] It should be understood that the numerous changes, modifications, and alternatives to the preceding disclosure can be made without departing from the scope of the disclosure. The preceding description, therefore, is not meant to limit the scope of the disclosure. Rather, the scope of the disclosure is to be determined only by the appended claims and their equivalents. It is also contemplated that structures and features in the present examples can be altered, rearranged, substituted, deleted, duplicated, combined, or added to each other.

What is claimed is:

1. A method of processing natural gas to produce liquefied natural gas (LNG) using a consolidated refrigeration and liquefaction module, comprising:

(a) cooling the natural gas in a first array of one or more heat exchangers using a first refrigerant from a first refrigerant circuit, wherein the first refrigerant is compressed in a first compressor;

(b) compressing a second refrigerant from a second refrigerant circuit in a second compressor;

(c) cooling and partially condensing the compressed second refrigerant using the first refrigerant in a second array of one or more heat exchangers located in the consolidated refrigeration and liquefaction module;

(d) separating the partially condensed second refrigerant into liquid and vapor phases using a refrigerant separator located in the consolidated refrigeration and liquefaction module; and

(e) liquefying the natural gas to produce LNG in a third array of one or more heat exchangers using the vapor and liquid phases of the partially condensed second refrigerant.

2. The method of claim 1, wherein the first array of one or more heat exchangers is located in the consolidated refrigeration and liquefaction module.

3. The method of claim 1, wherein the refrigerant separator is connected with the second array of at least one heat exchangers such the length of process piping connecting an inlet of the refrigerant separator and an outlet of the nearest heat exchanger in the second array of at least one heat exchangers is less than ten meters.

4. The method of claim 1, wherein the third array of one or more heat exchangers is located in the consolidated refrigeration and liquefaction module.

5. The method of claim 1, further comprising connecting the third array of heat exchangers to the consolidated refrigeration and liquefaction module at an operating site.

6. The method of claim 1, wherein the third array of one or more heat exchangers are installed in a module separate from the consolidated refrigeration and liquefaction module and are connected at an operating site to the consolidated refrigeration and liquefaction module.

7. The method of claim 1, further comprising:

prior to step (e), removing heavy hydrocarbon components from the natural gas using a scrub column installed in the consolidated refrigeration and liquefaction module.

8. The method of claim 1, further comprising:

in the consolidated refrigeration and liquefaction module, isentropically expanding the liquid stream of the partially condensed liquid refrigerant.

9. The method of claim 1, further comprising:

in the consolidated refrigeration and liquefaction module, isentropically expanding the LNG.

10. The method of claim 1, further comprising:

in the consolidated refrigeration and liquefaction module, providing components for (a) end-flashing the LNG and/or (b) nitrogen rejection.

11. The method of claim 1, further comprising:

including, in the consolidated refrigeration and liquefaction module, an accumulator vessel providing buffer liquid storage for the first refrigerant.

12. The method of claim 1, wherein a subcooling heat exchanger providing subcooling of the first refrigerant is included in the consolidated refrigeration and liquefaction module.

13. The method of claim 1, wherein the first refrigerant is propane and/or propylene and the second refrigerant is a mixed refrigerant that includes methane, ethane and/or ethylene and propane and/or propylene.

14. The method of claim 1, further comprising locating a fourth array of one or more heat exchangers in the consolidated refrigeration and liquefaction module.

15. The method of claim 1, further comprising: disposing an array of piping on the consolidated refrigeration and liquefaction module, the array of piping configured to connect components on the consolidated refrigeration and liquefaction module to other modules in an LNG facility in which the consolidated refrigeration and liquefaction module is located.

16. The method of claim 1, further comprising: disposing an array of piping on the consolidated refrigeration and liquefaction module, the array of piping configured to connect components on a first additional module in an LNG facility in which the consolidated refrigeration and liquefaction module is located, to a second additional module in the LNG facility.

17. A hydrocarbon processing plant, comprising:
- a first refrigerant circuit;
- a first refrigerant configured to circulate in the first refrigerant circuit;
- a first compressor configured to compress the first refrigerant;
- a first array of one or more heat exchangers configured to cool a hydrocarbon stream using the first refrigerant;
- a second refrigerant circuit;
- a second refrigerant configured to circulate in the second refrigerant circuit;
- a second compressor configured to compress the second refrigerant;
- a second array of one or more heat exchangers configured to cool and partially condense the compressed second refrigerant using the first refrigerant;
- a refrigerant separator configured to separate the partially condensed second refrigerant into liquid and vapor phases;
- a third array of one or more heat exchangers configured to liquefy the hydrocarbon stream using the vapor and liquid phases of the partially condensed second refrigerant; and
- a consolidated refrigeration and liquefaction module within which is located the second array of one or more heat exchangers and the refrigerant separator.

18. The hydrocarbon processing plant of claim 17, wherein the hydrocarbon stream is natural gas and the liquefied hydrocarbon stream is liquefied natural gas (LNG).

19. The hydrocarbon processing plant of claim 17, wherein the first array of one or more heat exchangers is located in the consolidated refrigeration and liquefaction module.

20. The hydrocarbon processing plant of claim 17, further comprising process piping connecting the refrigerant separator to the second array of at least one heat exchangers, wherein the length of process piping connecting an inlet of the refrigerant separator and an outlet of the nearest heat exchanger in the second array of at least one heat exchangers is less than ten meters.

21. The hydrocarbon processing plant of claim 17, wherein the third array of one or more heat exchangers is located in the consolidated refrigeration and liquefaction module.

22. The hydrocarbon processing plant of claim 17, wherein the third array of heat exchangers is connected to the consolidated refrigeration and liquefaction module at an operating site.

23. The hydrocarbon processing plant of claim 17, further comprising a second module, separate from the consolidated refrigeration and liquefaction module, within which the third array of one or more heat exchangers is installed.

24. The hydrocarbon processing plant of claim 17, further comprising:
- a scrub column, located in the consolidated refrigeration and liquefaction module, the scrub column configured to remove heavy hydrocarbon components from the hydrocarbon stream.

25. The hydrocarbon processing plant of claim 17, further comprising:
- an isotropic expansion component located in the consolidated refrigeration and liquefaction module and configured to isentropically expand the liquid stream of the partially condensed liquid refrigerant.

26. The hydrocarbon processing plant of claim 17, further comprising:
- an isotropic expansion component located in the consolidated refrigeration and liquefaction module and configured to isentropically expand the liquefied hydrocarbon stream.

27. The hydrocarbon processing plant of claim 17, further comprising components for (a) end-flashing the LNG and/or (b) nitrogen rejection, said components being located in the consolidated refrigeration and liquefaction module.

28. The hydrocarbon processing plant of claim 17, further comprising an accumulator vessel configured to provide buffer liquid storage for the first refrigerant, the accumulator vessel being located in the consolidated refrigeration and liquefaction module.

29. The hydrocarbon processing plant of claim 17, further comprising a subcooling heat exchanger configured to provide subcooling of the first refrigerant, the subcooling heat exchanger being located in the consolidated refrigeration and liquefaction module.

30. The hydrocarbon processing plant of claim 17, wherein the first refrigerant is propane and/or propylene and the second refrigerant is a mixed refrigerant that includes methane, ethane and/or ethylene and propane and/or propylene.

31. The hydrocarbon processing plant of claim 17, further comprising locating a fourth array of one or more heat exchangers located in the consolidated refrigeration and liquefaction module.

32. The hydrocarbon processing plant of claim 17, further comprising an array of piping disposed on the consolidated refrigeration and liquefaction module, the array of piping configured to connect components on the consolidated refrigeration and liquefaction module to other modules in the hydrocarbon processing facility in which the consolidated refrigeration and liquefaction module is located.

33. The hydrocarbon processing plant of claim 17, further comprising an array of piping on the consolidated refrigeration and liquefaction module, the array of piping configured to connect components on a first additional module in a hydrocarbon processing facility in which the consolidated refrigeration and liquefaction module is located, to a second additional module in the hydrocarbon processing facility.

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