

PROCESSES FOR BLENDING TWO OR MORE STREAMS OF LIQUIFIED HYDROCARBONS

Field of the Invention

[0001] The present specification generally relates to the field of blending of hydrocarbons, and more specifically, to processes to blend two or more streams of liquefied hydrocarbons.

Background of the Invention

[0002] This section is intended to introduce various aspects of the art, which may be associated with exemplary embodiments of the present invention. This discussion is believed to assist in providing a framework to facilitate a better understanding of particular aspects of the present invention. Accordingly, it should be understood that this section should be read in this light, and not necessarily as admissions of any prior art.

[0003] Generally, it is commercially important to cryogenically liquefy natural gas so as to produce LNG for more convenient storage and transport. A fundamental reason for the liquefaction of natural gas is that liquefaction results in a volume reduction, thereby making it possible to store and transport large volumes the liquefied gas in containers at low or even atmospheric pressure, in an economical manner, and thereby to provide a technically sound and safe solution, in situations where pipeline transport is not practical or economically feasible.

[0004] Blending of an LNG product, which comprises mainly methane with another component, such as light hydrocarbons, such as ethane, propane, or butane, to increase the LNG heating value to meet market demands is known. For instance, US20140338393 discloses a method for producing a blended mixture of liquefied natural gases to meet the particular requirements of an operator at a production facility, application site or a fueling station by blending together a lean liquefied natural gas and a rich liquefied natural gas. In another example, WO2005093017 discloses compositions comprising mixtures of natural gas and synthetic light hydrocarbons, such as C2 to C5 paraffins, olefins and mixtures thereof, obtained via a hydrocarbon synthesis reactions, which are suitable for use as fuel compositions, and particularly to blends of such synthetic light hydrocarbons and a natural gas derived from LNG produced in an LNG process. In yet another example, US8381544 discloses altering the heating value of a liquefied natural gas by adding higher heating value components by using the LNG to cool the higher heating value component stream prior to combining the higher heating value components with the LNG.

[0005] In addition, US 11416012 discloses in-line mixing of hydrocarbon liquids from a plurality of containers into a single pipeline, where the hydrocarbon liquids are generally those that exist in a liquid state at atmospheric conditions, such as hydrocarbons that exists as a viscous liquid in underground geological formations and at the surface, gasoline, crude oils, pyrolysis oil, etc. As such, this patent reference does not address the challenges of blending liquefied hydrocarbons.

[0006] These disclosures, however, do not address potential challenges associated with blending of two liquified hydrocarbon streams that have different properties, such as density. As such, it would be desirable to have an improved process to blend two or more liquified hydrocarbon streams. These and other objectives will become apparent from the disclosure provided herein.

Summary of the Invention

[0007] There is provided a method for blending two or more liquified hydrocarbon streams at a facility that comprises a first storage container for storing a first liquified hydrocarbon, which is optionally liquefied natural gas; a send out system to send the first liquified hydrocarbon to a downstream processing equipment, which optionally comprises regasification equipment; and a network of conduits. The network of conduits comprises (i) a first blending point located downstream of the first storage container and upstream of the send out system, (ii) a first conduits segment to provide fluid communication between the first storage container and the first blending point, (iii) a second conduits segment to provide fluid communication between a source of a second liquified hydrocarbon and the first blending point, optionally the second liquified hydrocarbon is selected from a group consisting of liquified ethane, liquified butane, liquified propane, and any combination thereof; and (iv) combined conduits to provide fluid communication between the first blending point and the send out system. The combined conduits comprise a first final valve immediately upstream of an inlet of the send out system. The method comprises: (a) pumping a first liquified hydrocarbon stream from the first storage container to the first blending point via the first conduits segment; (b) pumping a second liquified hydrocarbon stream from the source of the second liquified hydrocarbon to the first blending point via the second conduits segment; (c) combining the first and second liquified hydrocarbon streams at the first blending point in a volumetric ratio in a range from 1:500, preferably from 1:100, and up to 500:1 to provide a combined stream; (d) providing at least a portion, including all, of the combined stream from the first blending point to the send out system via the combined conduits, and (e) while the combined

stream is between a segment of the combined conduits between the first blending point and the first final valve, providing the combined stream with an operating pressure above (preferably at least 0.1 bar above, more preferably at least 0.5 bar above, most preferably at least 1.2 bar above) a saturation pressure of the combined stream.

[0008] Optionally, in some embodiments, the network of conduits further comprises return-combined conduits (160) to provide fluid communication between the first blending point and a storage container, optionally the storage container is the first storage container. The return-combined conduits comprise a second final valve immediately upstream of an outlet of return-combined conduits. In such embodiment, the method can further comprise providing at least a portion of the combined stream from a segment of the combined conduits upstream of the first final valve to a storage container; while the portion of the combined stream being in a segment of the combined conduits between the first blending point and the second final valve, providing the portion of the combined stream with an operating pressure above (preferably at least 0.1 bar above, more preferably at least 0.5 bar above, most preferably at least 1.2 bar above) a saturation pressure of the combined stream.

[0009] Optionally, in some embodiments, at least a portion, including all, of the combined stream is not provided to the storage container.

[0010] Optionally, in some embodiments, the combined conduits further comprise a first subsequent blending point located upstream of the first final valve and downstream of the first blending point, and optionally either upstream or downstream of the return-combined conduits. In such embodiment, the method can further comprise: (f) providing a second stream of the first liquified hydrocarbon from a source of the first liquified hydrocarbon, optionally the first storage container, to the first subsequent blending point; (g) combining the combined stream and the second stream of the first liquefied hydrocarbon at the first subsequent blending point in a volumetric ratio in a range from 25:1, preferably 50:1, and up to 500:1, wherein the first stream of the first liquefied hydrocarbon and the stream of the second liquefied hydrocarbon ethane stream are combined in a volumetric ratio in a range from 1:500, preferably 1:100, and up to 50:1 at the first blending point.

[0011] Optionally, in some embodiments, the combined conduits further comprise a second subsequent blending point located downstream of the final valve and upstream of the blended-product storage container. In such an embodiment, the method can further comprise: (f) providing

a third stream of the first liquified hydrocarbon from a source of the first liquified hydrocarbon to the second subsequent blending point, such source being different from the first storage container, and it can optionally comprise a boil-off gas management system (150); (g) combining the combined stream and the third stream of the first liquified hydrocarbon at the second subsequent blending point in a volumetric ratio in a range from 25:1, preferably 50:1, and up to 150:1, wherein the first LNG stream and ethane stream are combined in a volumetric ratio in a range from 1:500, preferably 1:100, and up to 50:1 at the first blending point and wherein the combined stream and the second stream of the first liquified hydrocarbon are combined in a volumetric ratio in a range from 100:1, preferably 150:1, and up to 500:1 at the first subsequent blending point.

[0012] Optionally, in some embodiments, the combined conduits further comprise a subsequent blending point located downstream of the final valve and upstream of the blended-product storage container. In such embodiment, the method can further comprise: (f) providing another stream of the first liquified hydrocarbon from a second source of the first liquified hydrocarbon to the subsequent blending point, optionally such source being different from the first storage container, optionally it comprises a boil-off gas management system; (g) combining the combined stream and the other stream of the first liquified hydrocarbon at the subsequent blending point (308) in a volumetric ratio in a range from 25:1, preferably 50:1, and up to 500:1, and wherein the first stream of the first liquified hydrocarbon and the stream of the second liquified hydrocarbon are combined in a volumetric ratio in a range from 1:500, preferably 1:100, and up to 50:1 at the first blending point.

[0013] Optionally, in some embodiments, the combined stream downstream of the first final valve and downstream of any subsequent blending point, and it can optionally also be downstream of the second final valve. In such embodiment, the combined stream can comprise a volumetric ratio of the first liquified hydrocarbon, preferably LNG, to the second liquified hydrocarbon, preferably liquified ethane, of at least 2:1, preferably at least 3:1, and more preferably 4:1.

[0014] Optionally, in some embodiments, the method can further comprise providing the network of conduits with an overall operating pressure of at least 2 barg.

[0015] Optionally, in some embodiments, the method can further comprise reducing the operating pressure of the combined stream downstream of the second final valve to less than the saturation pressure of the combined stream. In such embodiment, the method can further comprise

reducing the operating pressure of the combined stream downstream of the second final valve to the storage pressure of the storage container.

[0016] Optionally, in some embodiments, step (a) is preferably performed before step (b). In such embodiments, step (a) can comprise circulating the first stream of the first liquified hydrocarbon from the first storage container through the first portion of conduits, the combined conduits, optionally back to the first storage container, and optionally through a boil-off gas management system.

[0017] Optionally, in some embodiments, the second liquified hydrocarbon can be liquified ethane, and the source of liquified ethane is selected from the group consisting of onshore storage, and ethane transport vessel, and any combination thereof.

[0018] Optionally, in some embodiments, the facility can comprise an LNG regasification facility.

[0019] Optionally, in some embodiments, the method can further comprise providing the content of the storage container to the send out system.

Brief Description of the Drawings

[0020] FIG. 1 depicts a diagram of an exemplary embodiment of a system for use in blending two or more liquified hydrocarbon streams according to aspects disclosed in the present disclosure.

[0021] FIG. 2 depicts a diagram of an exemplary embodiment of another system for use in blending two or more liquified hydrocarbon streams according to aspects disclosed in the present disclosure.

[0022] FIG. 3 depicts a diagram of an exemplary embodiment of yet another system for use in blending two or more liquified hydrocarbon streams according to aspects disclosed in the present disclosure.

[0023] FIG. 4 depicts a diagram of an exemplary embodiment of yet another system for use in blending two or more liquified hydrocarbon streams according to aspects disclosed in the present disclosure.

Detailed Description of the Invention

[0024] The present invention will now be described in detail with reference to embodiments thereof as illustrated in the accompanying drawings. References to “one embodiment,” “an embodiment,” “an example embodiment,” etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily

include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described. Other suitable modifications and adaptations of the variety of conditions and parameters normally encountered in the field, and which would be apparent to those skilled in the art, are within the spirit and scope of the invention.

[0025] Although the description herein provides numerous specific details that are set forth for a thorough understanding of illustrative embodiments, it will be apparent to one skilled in the art that embodiments may be practiced without some or all of these specific details. In other instances, well known process steps and/or structures have not been described in detail in order to not unnecessarily obscure the present invention. The features and advantages of embodiments may be better understood with reference to the drawings and discussions that follow.

[0026] In addition, when like elements are used in one or more figures, identical reference characters will be used in each figure, and a detailed description of the element will be provided only at its first occurrence. Some features or components of the systems or processes described herein may be omitted in certain depicted configurations in the interest of clarity.

[0027] A general concern when blending an LNG product with lighter hydrocarbons is the potential formation of stratified liquid layers (or stratification) of different density, in a storage container. Typically, heat leaking into the blended-LNG product via the storage container walls, will slowly warm the blend-LNG in contact with the container walls and bottom plate. This warmer blended LNG has a lower density, which increases its buoyancy, slowly leading the warmer blended LNG to ascend in the bulk LNG inventory. At the top of the liquid column (liquid vapor interface), the warmer LNG releases the accumulated excess heat through vaporization, becoming cooler and denser, which in turn decreases its buoyancy, slowly leading the cooler blended LNG to descend in the bulk LNG inventory. This natural convection currents will occur uninterrupted, as long as, the difference in density within the blended LNG bulk inventory is less than 1%. In situations where the density in the bulk is greater than 1%, different LNG layers will form, interrupting the natural convection of the bulk LNG. When there is a potential for LNG blends with different density to be introduced in the same container, particularly such as in this case at least 10% difference in density between the lean LNG (methane) and liquified ethane, it is essential

to maintain the homogeneity and mitigate stratification. Once stratified liquid layers are formed, a rollover can occur when the density difference between the two layers becomes sufficiently small that the natural convection currents from the bottom layer come to the free surface. The subsequent mixing of these layers is accompanied by a large increase in the normal vaporization rate, which will be proportional to the amount of superheat accumulated in the bottom layer. This physical phenomenon associated with the mixing of stratified layers of LNG is commonly and descriptively referred to as “rollover”. A rollover of high intensity can result, however, in vapor release in excess of the designed vapor handling capabilities of the container and can thus overpressure and possibly rupture the storage container.

[0028] Although the present disclosure often refers to LNG and ethane as the two streams of liquefied hydrocarbons that benefit from the blending methods described herein, it is understood that the principles provided by the present disclosure can be applied to blend other streams of liquefied hydrocarbons, such as (i) LNG and liquified propane, or (ii) LNG and a mixture of liquified ethane, liquified propane, liquified butane, and any combination thereof.

[0029] As used herein, the term “hydrocarbon” has its ordinary meaning, which includes molecules comprised of carbon and hydrogen in various combinations, and may be of fossil (e.g., natural gas) or biogenic origin (e.g., biomethane). The term “liquified hydrocarbons” refers to hydrocarbons that occur as gases at atmospheric pressure and temperature, and due to a reduction of temperature and/or an increase of pressure, or a combination of both, will change state and become liquids at the new pressure and temperature conditions. In some cases (as it is the case of natural gas liquefaction) this phase change can also be coupled with a subsequent lowering of the operating pressure to meet downstream processes (e.g., atmospheric storage of LNG), further lowering the liquefied hydrocarbon stream temperature. The specific combination of pressures and temperatures at which the gases liquefy vary by the type of hydrocarbons. Furthermore, hydrocarbons may be described as being light or heavy according to the number of carbon atoms and hydrogen atoms in a molecule. Examples of liquified hydrocarbons include alkanes (or paraffins) (such as methane – CH_4 , ethane — C_2H_6 , propane— C_3H_8 , butanes: normal butane and isobutane— C_4H_{10} , natural gasoline or pentanes plus— C_5H_{12} and heavier); and alkenes (or olefins) (such as ethylene— C_2H_4 , propylene— C_3H_6 , normal butylene and isobutylene— C_4H_8 .

[0030] The present disclosure provides methods for conducting a blending operation of two streams of liquefied hydrocarbons to produce a liquefied natural gas with desired composition at

an LNG facility that mitigate the risk of stratification. Further, certain embodiments of the methods of the present disclosure allow routing of at least a portion, including all, of the blended product stream to the send-out system, with the option to bypass, partially or completely, a storage container. As used herein, the term send out system has its ordinary meaning and generally refers to pump equipment that sends a liquified hydrocarbon stream, such as LNG, to downstream processing, such as to convert the liquified hydrocarbon stream to vapor to be sent to a pipeline system for use by consumers, and/or loading of the liquified blended product for distribution, including ISO container, road or rail car, bunkering, etc.). For context, a facility, particularly a regasification facility typically provides a liquified hydrocarbon to the send out system for downstream processing via a storage container in fluid communication with such send out system. Embodiments of the present disclosure provides the option to provide the blended product to the send out system without first going with the blended-LNG stream through the storage container, thereby providing operational efficiency improvements. In addition, such bypass of a storage container reduces the need to engage the boil off gas (BOG) management system associated to manage the BOG that is formed from the portion that enters the receiving container. This is particularly relevant in assets where the BOG management system is an operational constraint, particularly a significant constraint. Furthermore, such bypass of a storage container reduces and even potentially eliminates any risk associated with stratification in the storage container, and can thereby enable a relaxation of the proposed mitigation measures. Embodiments of the present method can provide other additional benefits that are apparent to one of ordinary skill. In addition, certain embodiments of the methods described herein can be suitably adapted for blending of lean LNG with liquified ethane to meet desired LNG and/or natural gas specifications (such as the Wobbe Index (WI), Lower Heating Value (LHV), Methane Number (MN), or the Incomplete Combustion Factor (ICF)) at various LNG facilities or sites using existing infrastructure of the respective site.

[0031] FIGS. 1 - 4 depict various facilities that comprise an storage container 102 to store a first liquified hydrocarbon, preferably LNG, and a send out system 106 to provide a liquified hydrocarbon stream to downstream processing, such as regasification equipment. The depicted facilities further comprise a network of conduits in fluid communication with both the storage container 102 and the send out system 106. Optionally, the LNG facilities can further comprise return-combined conduits 160 to provide fluid communication between the combined conduit 116

and the storage container 102. Although FIGS. 1 – 4 depict conduits 160 as routing the combined stream from conduits 116 to container 102, it is understood that conduits can alternatively or additionally route the combined stream from conduits 116 to another suitable storage container (either onshore and/or a vessel), even if not explicitly depicted. In general, liquified natural gas (LNG) is natural gas (predominantly methane) that has been liquefied. It is understood that the figures omit certain portions of the network of the conduits, such as the recirculation and loading/unloading conduits, that are not being referenced explicitly but are still part of the facility as understood by one of ordinary skill. LNG can be stored in container 102 and/or 106 at a temperature lower than -110°C , depending on the application, and more typically lower than -145°C , such as between -159°C and -162°C . The LNG in container 102 is typically lean LNG at the beginning of the blending operations. In certain embodiments which involve routing the combined or blended stream back to container 102, then the composition of the LNG will be “richer” at the end of the blending operation as compared to the beginning. Generally speaking, “lean” LNG has a relatively lower calorific value whereas “rich” LNG contains a greater proportion of heavier hydrocarbons which gives it a higher calorific value. Lean LNG can be further enriched, such as by methods described herein, to meet various market quality specifications, such as the Wobbe Index (WI), Lower Heating Value (LHV), Methane Number (MN), or the Incomplete Combustion Factor (ICF).

[0032] The network of conduits comprises a first blending point, which may be referred to as an LNG-ethane blending point 108 in reference to a preferred embodiment, located between the jetty and the storage container (102). The network of conduits further comprises first conduits segment 110 (which may be referred to as LNG conduits 110 for a preferred embodiment where the first liquified hydrocarbon is LNG), and second conduits segment 112 (which may be referred to as ethane conduits 112 for a preferred embodiment where the second liquified hydrocarbon is ethane). First conduits segment 110 provides fluid communication between the first storage container 102 and first blending point 108. Second conduits segment 112 provides fluid communication between the storage container 114 for the second liquified hydrocarbon and the first blending point 108. Container 114 may be referred to as ethane source 114 as reference to a preferred embodiment in which the second liquified hydrocarbon is ethane. The first blending point 108 is a fluid conduit junction between the first conduits segment 110 and the second conduits segment 112. Preferably, the first blending point 108 is a junction at or near the

connection between the recirculation line and the unloading line. As can be seen, the blending point 108 is also upstream of the send out system 106. Blending point 108 is a fluid conduit junction known to one of ordinary skill. For instance, suitable examples of blending point 108 include a tee junction, Y-shape junction, a mixing tee, a wye pipe fitting, and any combination thereof.

[0033] In a preferred embodiment, the second liquified hydrocarbon is ethane. Liquified ethane can be stored at a temperature lower than -30°C , depending on the application, and more typically lower than -75°C , such as between -80°C to -89°C . Although FIG. 1 depicts the ethane source 114 as being on a vessel (such as a liquified ethane carrier), it is understood that ethane source 114 suitably can additionally or alternatively be an onshore storage container as known by one of ordinary skill. The network of conduits further comprises combined conduits 116 to provide fluid communication between the first blending point 108 and send out system 106 for downstream processing, such as to convert the liquified hydrocarbon stream to vapor to be sent to a pipeline system for use by consumers. In specific assets, such as Liquid-in Liquid-Out LNG assets, the send out system may include cryogenic distribution pipeline, or alternatively pump equipment and LNG loading facilities for LNG vessels (e.g., bunker vessels), LNG road tankers, LNG rail cars and/ or LNG ISO containers.

[0034] Suitable storage for liquefied hydrocarbons like LNG, liquefied ethane, and others that are noted herein, are known to one of ordinary skill. For example, suitable examples can include single containment systems that typically have an inner wall or primary container that holds the refrigerated liquid and can be self-supporting. The inner container can be surrounded by an outer wall, thereby forming an annular space, which can hold insulation. The single containment system can be further insulated, such as the base and roof, and external insulation. Another suitable example includes double containment systems which typically adds to the single containment system, a secondary wall that is capable of containing both liquid and vapor.

[0035] A first stream of a first liquified hydrocarbon, preferably liquefied natural gas (LNG), is pumped through the first conduits segment 110 (which may be referred to as LNG conduits 110 for a preferred embodiment), from the storage container 102 to the first blending point 108. Referring to FIG. 1, the pumping of the LNG stream can be done at least by pump equipment 120. A liquefied ethane stream is pumped through ethane conduits 112 from the ethane source 114 to the LNG-ethane blending point 108. As used herein, the term “liquified ethane”, “liquid ethane”

or “ethane” refers to a liquefied hydrocarbon stream comprising at least 50 mol%, preferably at least 95 mol%, of ethane. As noted elsewhere in the present disclosure, liquefied hydrocarbons other than LNG and liquefied ethane can be blended using the methods described herein. For instance, if LNG is being blended with liquefied propane, then the liquefied hydrocarbon stream that is liquefied propane comprises at least 50 mol%, preferably at least 95 mol% propane; and if liquefied butane, then the stream comprises at least 50 mol% butane, preferably at least 95 mol%. Optionally, if the liquefied hydrocarbon stream does not consist essentially of the component of its namesake (for instance, the liquefied ethane stream is not essentially all ethane), the remaining portion of that stream be selected from a group consisting of ethane, methane, propane, butane, and any combination thereof, as applicable. For instance, an example of a mixture of liquefied hydrocarbons as defined herein can be LPG, which stands for liquefied petroleum gas, which includes mixes that are mostly propane, mostly butane, or mostly a mixture of both propane and butane.

[0036] Referring to FIG. 1, the pumping of the liquefied ethane stream can be done at least by pump equipment 118. The first LNG stream and the ethane stream are combined at the LNG-ethane blending point 108 in a volumetric blending ratio of LNG to ethane in a range from 1:500 and up to 500:1, preferably 1:100 and up to 500:1, and more preferably 1:10 and up to 500 to 1, to provide a combined stream. It is understood that one of ordinary skill can select a suitable flow rate for the first LNG stream and the liquefied ethane stream to achieve a desired blending ratio in the range described herein, taking into consideration various factors, such as the specifications and safe operating envelope (SOE) of the equipment and infrastructures involved in the blending operation (e.g., network of conduits, pumps, storage containers, valves, etc.). The suitable number of pumps and types of pumps to implement the methods as described herein are known to one of ordinary skill. Additionally or alternatively, the pump equipment may be part of the existing infrastructure and equipment of the facility, such as a regasification plant.

[0037] In one embodiment, the combined stream can be provided to the blended-product storage send out system 106 via at least combined conduits 116 from the first blending point 108, with or without being returned to container 102 via conduits 160 and/or to another suitable storage container. In certain embodiments, if the combined stream is routed back to container 102, the product in container 102 can also be routed to the send out system 106, typically using existing infrastructure (not shown) of a particular facility, such as an LNG import facility. Preferably, the

flow rate of the LNG stream and the flow rate of ethane stream, by the respective pumps, provide suitable force to move the combined stream to the send out system 106, or to the LNG storage container 102 (or another storage container (not depicted)), without needing additional pump equipment.

[0038] The network of conduits can comprise a plurality of valves as known by one of ordinary skill to control the flow of various streams. For instance, referring to FIG. 1, optionally, LNG conduits 110 can comprise a valve 122 to control the flow of the first LNG stream flowing from storage container 102 to the LNG-ethane blending point 108. Optionally, ethane conduits 112 comprise valve 124 to control the flow of the liquified ethane stream flowing from ethane source 114 to the LNG-ethane blending point 108. In embodiments that include return-combined conduits 160, conduits 160 can comprise valve 162 to control the flow from combined conduits 116 to container 102 (and/or another suitable storage container (not shown)). Valve 162 can be manipulated or controlled to allow the combined stream to partially or completely bypass container 102. Regardless of the number of valves positioned throughout the network of conduits, such as LNG conduits 110, ethane conduits 112, and combined conduits 160 and 116, to control flow of the respective stream, the network of conduits comprises a final valve 126. Final valve 126 is the last valve that the combined stream flows through before it is introduced to send out system 106. That is, final valve 126 is the valve immediately upstream of an inlet of blended-product storage container send out system 106. For embodiments that also include return-combined conduits 160, valve 162 is also considered another final valve before the combined product is introduced to container 102.

[0039] At least during the blending operation, combined conduits 116, and optionally conduits 160, have an operating pressure due at least to the force exerted by the flow of the combined stream through the respective combined conduits 116, as well as, any available flow control devices in the conduits, such as the final valve 126, and optionally valve 162. While the combined stream is being provided to its destination, either send out system 106 and/or container 102 (or another container), the portion of the respective combined conduits, 116 and/or 160, between the LNG-ethane blending point 108 and upstream of the respective final valve, 126 and/or 162, is provided with an operating pressure that is higher than the saturation pressure of the combined stream, preferably at least 0.1 bar, more preferably at least 0.5 bar, and most preferably at least 1.2 bar above the saturation pressure of the combined stream. An operating pressure of at least 1.2 bar

higher than the saturation pressure of the combined stream is most preferred because it provides a most preferred buffer to accommodate fluctuations in pressure conditions along conduits 116, although embodiments with a lower operating pressure that is higher than the saturation pressure of the combined stream can still provide benefits described herein. The saturation pressure of the combined stream can change as it travels through conduits 116 to blended-product storage container 106, at least due to heat transfer from the environment and/or equipment. Generally, the saturation pressure of the combined stream increases as it travels through the combined conduits 116 toward container 106. Either the operating pressure of the combined conduits 116 between the LNG-ethane blending point 108 and final valve 126 is adjusted frequently, preferably in response to the monitoring, to accommodate the increase in saturation pressure and/or the saturation pressure of the combined stream can be reduced to ensure that the operating pressure remains higher than the saturation pressure of the combined stream as the saturation pressure changes. In addition to other benefits described elsewhere in the present disclosure, by providing an operating pressure of equal to or higher than the saturation pressure of the combined stream in the combined conduits 116 portion between blending point 108 and final valve 126, the methods described herein mitigates two phase flow formation in that portion of the combined conduits 116 (whether localized or sustained two phase flow formation). Thus, the methods described herein can minimize operational disturbances and equipment damage (e.g., cavitation driven erosion of valves) as known by one of ordinary skill. The term “saturation pressure” has its ordinary meaning and includes the definition of the pressure at which the fluid exists both as a vapor and liquid, and the rate of evaporation equals its rate of condensation for a given temperature. In this scenario, the saturation pressure of the combined stream is the pressure at which the combined stream exhibits both a vapor and liquid phase, which are in thermodynamic equilibrium at the temperature of the combined stream. The saturation pressure of the combined stream while in the respective combined conduits, 160 and/or 116, between the LNG-ethane blending point 108 and a respective final valve, 126 and/or 162 can be suitably determined by one of ordinary skill, based on the temperature of the combined stream and blending ratio (both of which can be measured by sensors). The network of conduits can comprise suitable sensors known to one of ordinary skill to provide the relevant data to implement the methods as described herein. Examples of suitable sensors include hydrometers, gravimeters, densitometers, density measuring sensors, gravity measuring sensors, pressure transducers, temperature sensors, flow meters, mass flow meters,

Coriolis meters, other measurement sensors to determine a density, gravity, or other variable as will be understood by those skilled in the art, or some combination thereof. The determination of the saturation pressure of the combined stream can be done manually, or autonomously using a computer or other similar process control systems such that subsequent corrective action (e.g., increase of the system operating pressure, increase of blending ratio, or other) may be implemented as desired. The methods described herein provide an operating pressure in the respective combined conduits, 116 and/or 160, between the LNG-ethane blending point 108 and a respective final valve, 126 or 162, that is higher than the saturation pressure of the combined stream, preferably at least 0.1 bar, more preferably at least 0.5 bar, and most preferably at least 1.2 bar above the saturation pressure of the combined stream. Providing such operating pressure that is higher than the saturation pressure of the combined stream enables the combined stream to remain in the liquid phase while flowing through these segments of conduits, despite varying pressure conditions along such conduits segments.

[0040] Suitably, the operating pressure of the combined stream in the combined conduits, as well as other parts of the network of conduits, can be monitored as known by one of ordinary skills, such as by sensors. The monitoring can allow for continuous monitoring of the operating conditions of the combined stream to ensure that the operating pressure in combined conduits 116 stays above (preferably at least 0.1, 0.5, or 1.2 bar above) the saturation pressure of the combined stream. Optionally and preferably, an operating pressure of the combined stream upstream of a respective final valve, 126 or 162, that is higher than the saturation pressure of the combined stream can be provided by adjusting the opening percentage of a respective final valve, 162 or 126, to provide the desired operating pressure upstream of the respective final valve. The opening percentage of the final valve 126 can be adjusted continuously as needed during the blending operation to provide the desired operating pressure at or above the saturation pressure of the combined stream as described herein.

[0041] Optionally, additionally or alternatively, the saturation pressure of the combined stream can be reduced by adjusting the volumetric ratio of the first LNG stream and liquefied ethane at the LNG-ethane blending point 108, and/or along the combined conduits 116 by providing additional blending points. In general, additional blending point(s) allows for more LNG to be added to the combined stream, which lowers the saturation pressure of the combined stream, thereby providing another option to ensure achieving of an operating pressure of the combined

stream that is higher than the saturation pressure of the combined stream. For instance, referring to FIG. 2, combined conduits 116 further comprises subsequent blending point 208 located upstream of valve 162, if present, and upstream of the final valve 126 and downstream of the LNG-ethane blending point 108. As can be seen in FIG. 2, the network of conduits further comprises another conduits segment 216 (which may be referred to as second LNG conduits 216 for a preferred embodiment) to provide fluid communication between storage container 102 (or a second suitable source of LNG, which is not depicted in FIG. 2) and subsequent blending point 208. In scenarios where the second LNG stream comes from storage container 102, second LNG conduits 216 can provide fluid communication between the subsequent blending point 208 and container 102 via a connection with LNG conduits 110 or it can connect directly to container 102. When desired, a second stream of the first liquified hydrocarbon, preferably LNG, can be provided to subsequent blending point 208 from storage container 102 (or a second source of LNG) via second LNG conduits 216. Optionally and preferably, second LNG conduits 216 can further comprise valve 222 to control the flow of the second LNG stream through the second LNG conduits 216. For instance, valve 222 can be closed when blending at subsequent blending point 208 is not desired and opened when blending of additional LNG to the combined stream is desired. The opening of valve 222 can be adjusted to achieve a desired blending ratio at subsequent blending point 208. In FIG. 2, the combined stream and the second LNG stream are combined in a ratio in a range from 25:1, preferably 50:1, and up to 500:1 at the subsequent blending point 208 and the first LNG stream and ethane stream are combined in a ratio in a range preferably from 1:100 and up to 50:1 at the LNG-ethane blending point 108. Because an additional blending point is provided, the ratio of LNG and ethane at the LNG-ethane blending point 108 can be less than if there is only a single blending point (i.e., 108). For instance, in a single-blending point scenario, the ratio of LNG to ethane at the LNG-ethane blending point is in a range from 1:500 and up to 500:1 versus a multi-blending-points scenario as depicted in FIG. 2, the ratio is in a range from 1:500, preferably from 1:100, and up to 50:1 of LNG to ethane at the LNG-ethane blending point 108 and from 25:1, preferably from 50:1, and up to 500:1 of combined stream to second LNG stream at the subsequent blending point 208. The provided blending ratio ranges, for a multi-blending-points scenario can be extended or changed, to suit asset and/ or process specific requirements, as understood by one of ordinary skill. For example, the first blending points may have a blending ratio of 1:1, while the second blending point may have a blending ratio of 47:1.

[0042] Optionally, additionally or alternatively, there can be a different blending point downstream of final valve 126. For instance, referring to FIG. 3, combined conduits 116 further comprises subsequent blending point 308 located downstream of the final valve 126 and upstream of the send out system 106. Optionally and alternatively, subsequent blending point 308 can be located upstream of the final valve 126, depending on the particular arrangement of the existing infrastructure of the plant at which the blending operation is carried out. The network of conduits can further comprise the BOG conduits 148 that provide fluid communication between the storage container 102 (and/ or the vapor space of other containers, both onshore and vessels, available at the LNG asset, although not depicted in the provided figures) and the Boil Off Gas (BOG) management system 150. During operation of LNG facility 100, including while LNG is stored in the container 102, BOG is produced in container 102 (and/ or others available in the LNG asset, although not depicted in the provided figures), at least due to heat leak from the environment and/or energy input from unloading pumps, and flashed vapors due to the pressure difference between the LNG transport ship and the storage container 106. The BOG (in vapour phase) is typically removed from storage container 102 (and/ or others available in the LNG asset, although not depicted in the provided figures) to mitigate the impacts of pressure build-up if the BOG is left in container 102. BOG management system 150 typically comprises a boil-off gas compressor and a condenser column to condense (although other technical options and configurations may apply) and recover the BOG as LNG, which is provided to send out system 116A via return conduits 316.

[0043] As can be seen in FIG. 3, the network of conduits further comprises a third LNG conduits 316 to provide fluid communication between a source of the first liquified hydrocarbon, such as LNG (which source can be different from container 102, optionally the BOG management system 150 as depicted), and subsequent blending point 308. When desired, another LNG stream can be provided to subsequent blending point 308 from the BOG management system 150 via third LNG conduits 316. While not depicted, it is understood that third LNG conduits 316 can further comprise a valve to control the flow of the LNG stream therethrough. In FIG. 3, the combined stream and the LNG stream from BOG management system 150 are combined in a ratio in a range from 25:1, preferably from 50:1, and up to 500:1 at the subsequent blending point 208 and the first LNG stream and ethane stream are combined in a ratio in a range preferably from 25:1, preferably 50:1, and up to 500:1 at the LNG-ethane blending point 108. For a multi-blending-points scenario depicted in FIG. 3, the blending ratio of LNG to ethane at the LNG-ethane blending point 108 is

in a range from 1:500, preferably from 1:100, and up to 50:1, and at the subsequent blending point 308, the ratio of the combined stream to the LNG stream from the BOG management system 150 is in a range from 25:1, preferably from 50:1, and up to 500:1 at the blending point 308.

[0044] Referring to FIGS. 3 and 4, the network of conduits can further optionally comprise conduits 152, downstream of blending point 108 and blending point 208, if present, to provide fluid communication between combined conduits 116 and BOG management system 150. At least a portion of the combined stream can be provided to the BOG management system 150 for the purpose of recondensing the BOG stream 148 (and/ or other BOG streams originating from other LNG storage containers or processes onsite, although not depicted in the provided figures) as standard in recondenser based BOG management systems. The blend-LNG conduit 152 can further comprise a valve (not shown) to allow for control over the amount of combined stream, if any, to provide to BOG management system 150. Optionally, alternatively or additionally, the blended LNG stream 152 may service another purpose within or outside of the BOG management system 150, not represented in the provided figures.

[0045] Optionally, additionally or alternatively, both additional blend points can be present along with the LNG-ethane blend point 108. For instance, referring to FIG. 4, combined conduits 116 comprises both subsequent blending point 208 and subsequent blending point 308 as described in FIGS. 2 and 3, respectively. For the multi-blending-points scenario depicted in FIG. 4, the blending ratio of (i) LNG to ethane at the LNG-ethane blending point 108 is in a range from 1:500, preferably from 1:100, and up to 50:1, (ii) the combined stream to the second LNG stream at the subsequent blending point 208 is in a range from 25:1, preferably from 50:1, and up to 150:1, and (iii) the combined stream to the LNG stream from BOG management system 150 at the subsequent blending point 308 is in a range from 100:1, preferably from 150:1, and up to 500:1. Depending on the particular configuration of the asset implementation this blending process, the network of conduits can comprise more than three blending points depicted in the figures (such as 108, 208, and 308) to achieve the desired operating pressure that is higher than the saturation pressure of the combined stream. The provided blending ratio ranges, for a multi-blending-points scenario can be extended or changed, to suit asset and/ or process specific requirements, as understood by one of ordinary skill. For example, the first blending point (such as 108) may have a blending ratio of the first liquified hydrocarbon stream to the second liquified hydrocarbon stream of 1:1, while

subsequent blending points (such as 208 and/or 308) may have a blending ratio of 47:1 of the combined stream to the first liquified hydrocarbon stream.

[0046] Optionally and preferably, various blending scenarios (such as single or multi blending point) and blending ratio within the provided ranges can be selected to achieve the volumetric blending ratio of LNG to ethane of at least 2:1, preferably at least 3:1, more preferably at least 4:1, in the combined stream that is downstream of final valve 162 and/ or the final valve 126 (for a scenario involving a single blending point and/or multi-blending points with the subsequent blending point 208) or downstream of subsequent blending point 308 (for the scenarios that include blending point 308).

[0047] It is understood that the BOG management system 150 can be present in other figures, such as FIG. 1, even though not depicted, where BOG conduits 148 are present to provide fluid communication between storage container 102 (or other containers or vessels present onsite) and BOG management system 150 to manage BOG build-up in storage container 102 (or other containers or vessels present onsite), as described herein and known to one of ordinary skill, including as part of the existing infrastructure of the LNG plant. The BOG management system 150 can be bypassed during the blending operation, such as shown in at least FIGS. 1 and 2.

[0048] Optionally and preferably, the first LNG stream is pumped to the LNG-ethane blending point 108 at a volumetric flow rate and pressure, which may be adjusted throughout the blending operation to meet the relevant process requirements. Although the flow rate and pressure of the first LNG stream pumped to blending point 108 may be adjusted, it is preferred to minimize the rate of change in the operation of the first LNG stream to a reasonable and/or practical extent. Meanwhile, the volumetric flow rate and pressure of the liquified ethane stream in ethane conduits 112 may be suitably adjusted, as known to one of ordinary skill, to meet the desired blending ratio at the LNG-ethane blending point 108, in a range from 1:500, preferably from 1:100 to 500:1 of LNG to liquefied ethane, for a single blending point, or the various ranges of blending ratios at other blending points in scenarios that include multi-blending points as described herein.

[0049] Embodiments described in the present disclosure provide options for implementation, such as a selection between a single-point blending operation or a multi-point process, to allow for consideration of various factors in optimizing the blending operation as desired. For instance, at a facility with hydraulic limitations in a conduits segment that is upstream of the first blending point 108 (such as at least a portion of conduits 110 leading to the first blending point having a

reduced inner diameter, such as one that is 12 inches or smaller or one that is smaller than the diameter of conduits 116 and/or conduits 112). A multi-point blending operation may be more suitable for such a scenario because such limitations can limit a single-point blending operation, such as in terms of flow rate and blending ratio possibilities (including a reduction of the amount of the second liquified hydrocarbon that can be blended) and higher operational costs. In addition, a multi-point blending operation allows for improve control and flexibility of the overall operation.

[0050] Referring to FIGS. 1 - 4, combined conduits 116 continue through final valve 126 to provide the combined stream (which can be from single or multi blending point(s)) send out system 106, which is downstream of final valve 126. Optionally and preferably, the operating pressure of the combined stream is increased by the send out system 106 to generate a pressurized combined stream to provide to a downstream LNG vaporizer system to produce a regasified natural gas stream that has a pressure suitable to enter a fluidly connected natural gas utility grid. Suitable means or equipment to increase the pressure at the send out system 106 is provided elsewhere in the present disclosure and can be selected by one of ordinary skill based on conditions and parameters particular to a certain facility or equipment.

[0051] Optionally, additionally or alternatively, the operating pressure of the combined stream in the respective combined conduits 116 (including 116A) and/or 160 and 116A can also be influenced by operating conditions of downstream systems in communication with the conduits located downstream of a respective final valve 162 or 126, as understood by one of ordinary skill.

[0052] Optionally, the blending operation can be further improved, such as a reduction in the amount of time to complete the blending operation, by providing a receiving storage container (a storage container to which the combined stream is being provided, such as container 102) with an operating pressure that is higher than the saturation pressure of the combined stream. It is understood that the higher operating pressure is subject to limitations imposed by the safety operating parameters of the respective storage container. Preferably, the operating pressure of the container receiving the combined stream is at least 5% higher, more preferably at least 50%, and most preferably at least 100% higher than the saturation pressure of the combined stream. A suitable way to provide such container with the operating pressure higher than the saturation pressure of the combined stream is to adjust the BOG pressure setpoint as known to one of ordinary skill.

[0053] The option to provide a receiving storage container with a higher operating pressure than the saturation pressure of the combined stream, is subject to limitations imposed by safety operating parameters of the respective storage container, is not typical in standard operational practice (primarily storage of liquified hydrocarbon for transport) for these storage containers, and it can be exercised as desired. If employed, the higher operating pressure is temporarily provided to the respective storage container during part or all of the duration of the blending operation, or even maintained after the blending operation, as desired.

[0054] Generally, for storage, it is desirable to maintain the operating pressure relatively low, preferably as low as possible within the relevant technical and contractual constraints, to maintain the temperature of the product in the storage container correspondingly low, thereby optimizing the volumetric capacity of the storage container and reducing BOG formation. Long term, the lower operating pressure is further desirable because it can help minimize changes in LNG quality over time. It is understood that the standard practice of keeping a low operating pressure for the receiving storage container is also available as an option for selection during part or all of the blending operation. Implementing a desired operating pressure for a particular receiving container is achieved primarily by managing the BOG of the respective container, which is typically done through the associated BOG management system. By providing the applicable storage container(s) with a higher operating pressure during the blending operation, the flashing of the combined stream when it enters the respective storage container is reduced or even potentially eliminated, thereby minimizing or even eliminating the rate of boil off gas formation associated with the blending operation. A minimal or zero BOG formation rate during blending operation relaxes the constraints on the boil off gas management, which decreases the operational time. Once the blending operation is completed, the operating pressure of the respective container may be reduced to return it to the standard operating pressure, or optionally maintained as per the relevant technical and contractual constraints impose to the vessel and its cargo. The BOG can be managed using standard operating procedures after blending operation, thereby allowing the blending operation to proceed without any time delays associated with the BOG management.

[0055] The methods of the present disclosure address certain negative impacts of in-tank blending two different liquified hydrocarbons, such as stratification, by promoting the inline blending of two different liquified hydrocarbons in a conduit under an operating pressure that is higher than the saturation pressure of the combined stream. Because the saturation pressure of the

combined stream can vary throughout its journey from the blending point 108 to its destination, such as back to container 102, reference to the “saturation pressure of the combined stream” is generally in the context of a particular segment of conduits. Adjusting the blending ratios and/or providing additional blending points as described herein are some suitable ways of manipulating the operating pressure of a relevant segment of conduits and/or influencing the saturation pressure of the combined stream in the relevant segment to achieve the desired level of operating pressure that is higher than the saturation pressure of the combined stream to ensure it stays in liquid state.

[0056] Additionally, the methods described herein further provide an option to minimize the BOG management requirements during the blending operation, thereby decreasing operational time of the blending operation, by providing the respective receiving storage container with an operating pressure that is higher than the saturation pressure of the combined stream to minimize flashing of the combined stream as it enters the respective storage container.

[0057] As noted in the present disclosure, the methods herein can be employed to conduct a blending operation of two streams of liquefied hydrocarbons, such as LNG and liquefied ethane, particularly at existing facility using the infrastructure already being used in standard operations, such as LNG regasification. For instance, an LNG facility delivering LNG or natural gas to downstream users aims to deliver “rich” LNG to downstream users, whilst being limited by incoming lean LNG from global markets, the methods described herein can be used to add liquefied ethane (or another lighter hydrocarbon or mixture of light hydrocarbons) to the LNG from the facility using existing infrastructure, such as pump equipment, conduits, and valves, etc. When the blending operation is desired, certain operating parameters of the facility can be changed to implement the methods described herein.

[0058] During standard operation, the LNG import facility is operated under its standard parameters to enable the regasification of LNG. When blending of LNG with another liquified hydrocarbon is desired, the methods described herein can be employed with minimal changes to the existing infrastructure and ease of transition between blending mode and normal plant operation mode, such as send out for downstream processing. Before the blending operation begins, the product in storage container 102 is typically lean LNG that can be further enriched with another liquified hydrocarbon. Prior to combining the lean LNG with another liquified hydrocarbon, such as ethane, the lean LNG from the storage container 102 to the LNG jetty and back to the LNG storage container (such as from container 102 to blending point 108 via conduits

110 (or another similar conduits) back to container 102 (or another container) via conduits 160, with going through the BOG management system 150 (partially or completely such as shown in FIGS. 3 and 4) and to the send out system 106 or completely bypassing the BOG management system 150 (such as shown in FIGS. 1 and 2)).

[0059] Before the second liquified hydrocarbon stream is provided to the first blending point 108, the lean LNG from storage container 102 is preferably provided first to the blending point 108 and at least to send out system 106 via conduits 116, and optionally back to container 102 (both can be as part of normal send out operation) and to 106, to ensure cooling of the blending pathway for at least the combined stream. After circulation of the first liquified hydrocarbon is established, the second liquified hydrocarbon stream can be pumped from the second container 114 according to aspects described in the present disclosure to begin the blending operation. This includes providing the combined stream to the send out system 106 at an operating pressure that is higher than the saturation pressure of the combined stream. Additional benefits of recirculating the LNG (under various circulation scenarios) (i) prior to the addition of the second liquified hydrocarbon (such as liquified ethane) and (ii) during blending operation include keeping the various conduits cold to minimize formation of vapor, particularly at blending point 108, and to facilitate mixing. Also, if desired and the equipment is available, the circulation of LNG provides LNG to the BOG management system 150, which enables the recondensation of BOG upstream of the LNG send out system 106. The circulation of the lean LNG as described can be suitably facilitated by various pump equipment, such as pumps 118 and 120. Once the lean LNG recirculation has been established, if not already being done, the liquified ethane stream can be pumped from the ethane source 114 according to aspects described in the present disclosure to begin the blending operation. That is, the first LNG stream is pumped into the network of conduits before the liquified ethane stream.

[0060] The combined stream can be provided back to container 102 or another container as part of the circulation or recirculation route, while having an operating pressure of higher than the saturation pressure of the combined stream at least in the portion of conduits 116 between the blending point 108 and final valve 162. Additionally or alternatively, certain embodiments of the methods described herein provide an option to partially or completely by pass a storage container, such as container 102, by routing the combined stream to send out system 106 without any being provided to a container, such as 102, via conduits 160, under an operating pressure of higher than

the saturation pressure of the combined stream at least in the portion of conduits 116 between the blending point 108 and final valve 126. The operating pressure of the combined stream is increased by the send out system 106 to generate a pressurized combined stream to provide to a downstream LNG vaporizer system to produce a regasified natural gas stream that has a pressure suitable to enter a fluidly connected natural gas utility grid. Suitable means or equipment to increase the pressure at the send out system 106 is provided elsewhere in the present disclosure and can be selected by one of ordinary skill based on conditions and parameters particular to a certain facility or equipment.

[0061] The operating parameters of the blending operation as described herein impacts the operating pressure of the network of conduits as compared to standard operating parameters. Optionally and preferably, the network of conduits is provided with an operating pressure of at least 2 bar g (bar gauge) to accommodate the impacts from the blending operation while meeting operational parameters. Suitable methods to provide the network of conduits with such operating pressure are known to one of ordinary skill. Once the blending operation is completed, such as when the desired amount of the second liquified hydrocarbon, such as liquified ethane, has been blended, the liquified ethane stream is ramped down and stopped. Standard operation resumes, including returning the operating pressure of the network of conduits to its standard parameters. The properties of the regasified blended product downstream of the send out system 106, preferably “rich” LNG relative to the LNG prior to blending, can be constantly monitored (e.g., Wobbe Index) to ensure the natural gas being provided to the utility grid meets certain specifications, such as quality, flow rate, and pressure. During the blending operation, information about the quality of the regasified blended product (e.g., Wobbe Index) is preferably provided to the blending operation to allow for adjustment of the blending ratio between the two liquified hydrocarbon streams to ensure the regasified blended product stream meets desired product quality specifications. The same philosophy applies for applications where the blend LNG is supplied to other downstream users, as it is the case in Liquid-in and Liquid-Out terminals (as described in [0031]). For embodiments in which the operating pressure of the respective storage container, such as 102, has been increased to be above the saturation pressure of the combined stream, the operating pressure of the respective container may be also reduced to its standard parameters. After the blending operation, the blended product in container 102 can be stored as inventory, or otherwise managed, such as distribution pursuant to contractual obligations.

[0062]

[0063] In applications where the combined stream may be recirculated or distributed amongst various storage containers (not shown) such that at least a portion, including all, of the combined stream, is provided to a blending point as if it were lean LNG, accumulation of the second liquified hydrocarbon (such as liquified ethane) may occur. That is, as the blending operation is performed for a period of time, the first liquified hydrocarbon stream that is pumped to the first blending point 108 comprises an increasing amount of the second liquified hydrocarbon over time. Such accumulation can be accounted for by adjusting the blending ratio at LNG-ethane blending point 108. LNG facilities typically include equipment to continuously monitor the properties of the LNG flowing through the network of conduits, including sensors (e.g., flow). The continuous monitor allows for continuous adjustment of flow of the respective streams, preferably the liquified ethane stream, to achieve desired blending ratios.

[0064] Optionally and preferably, the flow of the combined stream in the part of the combined conduits 160 and 116 upstream of the valve 162 and the final valve 126 is preferably carried out under turbulent flow regime.

[0065] While not depicted, it is understood that the principles described herein can be applied to provide blending between a liquified ethane carrier and a floating storage and regasification unit (FSRU), which typically comprises an LNG storage container, a BOG management system, and a send out system.

[0066] The methods provided herein, which include in-line mixing of the first LNG stream and the liquified ethane stream, particularly under turbulent flow regime, can maximize mixing of the LNG and liquefied ethane in the combined stream, thereby enabling the combined stream to exhibit a homogenous composition and characteristics (e.g., density), such that it can be provided to storage container 102 (or other containers, whether onsite or on a vessel) and/or to the send out system 106 in homogenous condition, which mitigates the risk for fluid stratification, or commercial issues at the point of custody transfer (e.g., natural gas grid injection point). In-line blending operations, however, can introduce partial vaporization with two-phase flow formation due to the difference in specific enthalpy of the lean LNG and liquid ethane streams, which can lead to the undesirable risk of excessive piping vibrations that lead to stress and fatigue of the pipes. The methods described herein address the potential two-phase flow formation by

maintaining the operating pressure in the combined stream to be higher than the combined stream saturation pressure.

[0067] While not shown, it is understood that a computer program can be used to control and/or implement some, including all, aspects of the methods described herein. This computer program may be referred to as a controller. For instance, the computer program can be used to control the pump discharge pressure and flow, the system operating pressure via the manipulation of the flow control valve opening percentage, among others. A suitable computer program includes one that is executed by a data processor. As used herein, reference to a computer program is intended to be equivalent to a reference to a program element and/or a computer readable medium containing instructions for controlling a computer system to coordinate the performance of the above described method. The computer program may be implemented as computer readable instruction code by use of any suitable programming language, such as, for example, JAVA, C++, and may be stored on a computer-readable medium (removable disk, volatile or nonvolatile memory, embedded memory/processor, etc.). The instruction code is operable to program a computer or any other programmable device to carry out the intended functions. The computer program may be available from a network, such as the World Wide Web, from which it may be downloaded. The various aspects described herein may be realized by means of a computer program respectively software; however, they may also be realized by means of one or more specific electronic circuits respectively hardware. Furthermore, the invention may also be realized in a hybrid form, i.e. in a combination of software modules and hardware modules. Additionally or alternatively, any or all aspects of the methods described herein can be performed manually by one or more human operator with relevant operational knowledge of the facility.

[0068] While specific embodiments have been described herein, it is understood that such descriptions are not intended to limit the described embodiments. Instead, any combination of the features and elements provided above, whether related to different embodiments or not, is contemplated to implement and practice contemplated embodiments. Furthermore, although embodiments disclosed herein may achieve advantages over other possible solutions or over the prior art, whether or not a particular advantage is achieved by a given embodiment is not limiting of the scope of the present disclosure. Thus, the aspects, features, embodiments and advantages described herein are merely illustrative and are not considered elements or limitations of the appended claims except where explicitly recited in a claim(s).

CLAIMS

1. A method for blending two or more liquified hydrocarbon streams at a facility comprising:

- a first storage container (102) for storing a first liquified hydrocarbon, optionally the first liquified hydrocarbon is liquefied natural gas,
- a send out system (106) to send the first liquified hydrocarbon to a downstream processing equipment, optionally the downstream processing equipment comprises regasification equipment, and

- a network of conduits comprising
 - i. a first blending point (108) located downstream of the first storage container (102) and upstream of the send out system (106),

- ii. a first conduits segment (110) to provide fluid communication between the first storage container (102) and the first blending point (108),

- iii. a second conduits segment (112) to provide fluid communication between a source of a second liquified hydrocarbon (114) and the first blending point (108), optionally the second liquified hydrocarbon is selected from a group consisting of liquified ethane, liquified butane, liquified propane, and any combination thereof;

- iv. combined conduits (116) to provide fluid communication between the first blending point (108) and the send out system (106), wherein the combined conduits (116) comprise a first final valve (126) immediately upstream of an inlet of the send out system (106),

wherein the method comprises:

- (a) pumping a first liquified hydrocarbon stream from the first storage container (102) to the first blending point (108) via the first conduits segment (110);
- (b) pumping a second liquified hydrocarbon stream from the source of the second liquified hydrocarbon (114) to the first blending point (108) via the second conduits segment (112);
- (c) combining the first and second liquified hydrocarbon streams at the first blending point (108) in a volumetric ratio in a range from 1:500, preferably from 1:100, and up to 500:1 to provide a combined stream; and

(d) providing at least a portion, including all, of the combined stream from the first blending point (108) to the send out system (106) via the combined conduits (116), and

(e) while the combined stream being in a segment of the combined conduits (116) between the first blending point (108) and the first final valve (126), providing the combined stream with an operating pressure above (preferably at least 0.1 bar above, more preferably at least 0.5 bar above, most preferably at least 1.2 bar above) a saturation pressure of the combined stream.

2. The method of claim 1, wherein the network of conduits further comprises return-combined conduits (160) to provide fluid communication between the first blending point (108) and a storage container, optionally wherein the storage container is the first storage container (102), wherein the return-combined conduits (160) comprise a second final valve immediately upstream of an outlet of return-combined conduits, wherein the method further comprises:

providing at least a portion of the combined stream from a segment of the combined conduits upstream of the first final valve (126) to a storage container

while the portion of the combined stream is between a segment of the combined conduits (116) between the first blending point (108) and the second final valve (126), providing the portion of the combined stream with an operating pressure above (preferably at least 0.1 bar above, more preferably at least 0.5 bar above, most preferably at least 1.2 bar above) a saturation pressure of the combined stream.

3. The method of claim 2, wherein at least a portion, including all, of the combined stream is not provided to the storage container (102).

4. The method of any prior claims, wherein the combined conduits (116) further comprise a first subsequent blending point (208) located upstream of the first final valve (126) and downstream of the first blending point (108), and optionally either upstream or downstream of the return-combined conduits (160), wherein the method further comprises:

(f) providing a second stream of the first liquified hydrocarbon from a source of the first liquified hydrocarbon, optionally the first storage container (102), to the first subsequent blending point (208);

(g) combining the combined stream and the second stream of the first liquefied hydrocarbon at the first subsequent blending point (208) in a volumetric ratio in a range from 25:1, preferably 50:1, and up to 500:1, wherein the first stream of the first liquefied hydrocarbon and the stream of the second liquefied hydrocarbon ethane stream are combined in a volumetric ratio in a range from 1:500, preferably 1:100, and up to 50:1 at the first blending point (108).

5. The method of claim 4, wherein the combined conduits (116) further comprise a second subsequent blending point (308) located downstream of the final valve (126) and upstream of the blended-product storage container (102), wherein the method comprises:

(f) providing a third stream of the first liquefied hydrocarbon from a source of the first liquefied hydrocarbon to the second subsequent blending point (308), optionally wherein said source being different than the first storage container (102), and optionally comprising a boil-off gas management system (150);

(g) combining the combined stream and the third stream of the first liquefied hydrocarbon at the second subsequent blending point (308) in a volumetric ratio in a range from 25:1, preferably 50:1, and up to 150:1, wherein the first liquefied hydrocarbon stream and second liquefied hydrocarbon stream are combined in a volumetric ratio in a range from 1:500, preferably 1:100, and up to 50:1 at the first blending point (108) and wherein the combined stream and the second stream of the first liquefied hydrocarbon are combined in a volumetric ratio in a range from 100:1, preferably 150:1, and up to 500:1 at the first subsequent blending point (208).

6. The method of claim 1, wherein the combined conduits (116) further comprise a subsequent blending point (308) located downstream of the final valve (126) and upstream of the blended-product storage container (102), wherein the method comprises:

(f) providing another stream of the first liquefied hydrocarbon from a source of the first liquefied hydrocarbon to the subsequent blending point (308), optionally wherein said source being different from the first storage container (102), and optionally comprising a boil-off gas management system (150);

(g) combining the combined stream and the other stream of the first liquefied hydrocarbon at the subsequent blending point (308) in a volumetric ratio in a range from 25:1, preferably 50:1, and up to 500:1, and wherein the first stream of the first liquefied hydrocarbon and the stream of

the second liquified hydrocarbon are combined in a volumetric ratio in a range from 1:500, preferably 1:100, and up to 50:1 at the first blending point (108).

7. The method of any prior claims, wherein the combined stream downstream of the first final valve (126) and downstream of any subsequent blending point (308), and optionally downstream of the second final valve (162), comprises a volumetric ratio of the first liquified hydrocarbon, preferably LNG, to the second liquified hydrocarbon, preferably liquified ethane, of at least 2:1, preferably at least 3:1, and more preferably 4:1.

8. The method of any prior claim further comprising: providing the network of conduits with an overall operating pressure of at least 2 barg.

9. The method of any prior claim, further comprising: reducing the operating pressure of the combined stream downstream of the second final valve (162) to less than the saturation pressure of the combined stream.

10. The method of claim 9, further comprising reducing the operating pressure of the combined stream downstream of the second final valve (162) to the storage pressure of the storage container (102).

11. The method of any prior claims wherein step (a) is performed before step (b).

12. The method of claim 11, wherein step (a) comprises circulating the first stream of the first liquified hydrocarbon from the first storage container (102) through the first portion of conduits (110), the combined conduits (116), optionally back to the first storage container (102), and optionally through a boil-off gas management system (150).

13. The method of any prior claims wherein the second liquified hydrocarbon is liquified ethane, and the source of liquified ethane is selected from the group consisting of onshore storage, and ethane transport vessel, and any combination thereof.

14. The method of any prior claims wherein the facility comprises an LNG regasification facility.
15. The method of any prior claims further comprising providing the content of the storage container (102) to the send out system (106).