The various embodiments herein provide a method and system for a process configuration with internal refrigeration for light gas and a process configuration with external refrigeration system for rich gas. The self-refrigeration unit comprising an open-closed cycle of refrigeration provides a required refrigeration load and the external refrigeration unit provides a refrigeration load corresponding to variations in a feed composition percentage. The configuration with internal refrigeration system utilizes a slip stream from or near the bottom of the demethanizer as a mixed refrigerant.
FIG. 2

Heat Flow (cal/hour)

Temperature (°C)

Cold Composite
Hot Composite
FIG. 3

Heat Flow (cal/hour)

Temperature (°C)

Cold Composite

Hot Composite
FIG. 5
FIG. 6

Graph showing the required refrigeration kW for different feeds with Internal and External Refrigeration.
FIG. 7

- Cold Composite
- Hot Composite
FIG. 8

Heat Flow (cal/hour)

Temperature (°C)

Cold Composite

Hot Composite

0  2  4  6  8  10  12

Heat Flow (cal/hour)
FIG. 9
FIG. 10
SYSTEM AND METHOD FOR RECOVERING
NATURAL GAS LIQUIDS WITH AUTO
REFRIGERATION SYSTEM

BACKGROUND

[0001] 1. Technical Field

[0002] The embodiments herein generally relate to a recovery process of natural gas liquids. The embodiments herein particularly relate to a recovery process of natural gas liquids with high level of liquids recovery and more particularly relates to a process of reducing an amount of refrigeration load in a recovery process of the natural gas liquids.

[0003] 2. Description of the Related Art

[0004] Natural gas liquids (NGL) recovery refers to the process of removing and gathering heavier hydrocarbon products from natural gas. These heavier hydrocarbons must be separated from methane to be recovered as natural gas liquids. These valuable natural gas liquids consist of ethane, propane, butane, and other heavier hydrocarbons. The increase in energy resources, costs and also economic issues, resulted in more complex and more efficient recovery units for recovering the gaseous liquids. New generation of NGL units have been created based on the reduction of fixed and operating costs for a defined output.

[0005] The existing processes designated to update process configurations are defined to aim at finding the new ways for maximizing the efficiency of existing equipments and reducing the operational costs. The major costs of the NGL recovery system are related to the refrigeration required for gas refrigerating. In the low temperature configurations, the required level of refrigeration is provided through a propane refrigeration cycle. In some cases, the mixed refrigerants and cascade refrigeration systems are used. Besides a refrigeration cycle, some amount of refrigeration load is either provided by Joule-Thomson expansion or expansion through a turbo expander. In a configuration, the required level of refrigeration depends on the integration of the processes and the number of cool boxes. The combined heating and cooling curves of the heat exchangers indicate an efficiency of this type of equipments. The optimal combined curves and high efficiency of cool boxes enable to achieve more integrated configurations. The more integrated a unit is, the lesser will be the fixed and operating costs.

[0006] A gas composition highly affects an economic situation of the NGL recovery unit and a selection of the process. The gas containing higher amounts of hydrocarbons, which can turn into liquid, will generate more liquid products resulting in a higher efficiency in return for the applied equipments. The richer the gas, the more is refrigeration load and a constant investment cost and also the heat exchangers with a higher heat transfer level are required. The light gases need more specific process conditions to reach to the higher recovery levels. In the units where the gas feed is rich, the usage of an external refrigeration system for achieving the higher recovery levels would be inevitable. In the case of the light gases there is no need to use the external refrigeration systems for achieving the higher recovery levels.

[0007] There are many expansion processes, which are commonly applied for the high compression feeds for recovering the liquid hydrocarbons in the gas process industries, specifically in the recovery of ethane and propane. In many of the conventional processes of NGL expansions, the gas feeds are refrigerated near to a relatively low temperature aiming at a partial liquidation, typically through a heat exchanger with a gas stream existing out from the upper section of the distillation tower and the lateral boilers. Some of the other existing techniques use propane as a refrigerant for external refrigeration or the propane refrigeration (PR) in the recovery of the heavier hydrocarbons.

[0008] As an improvement over the conventional processes, a new process called Gas Sub cooled Process (GSP) was developed. This process modified prevalent processes in some different parts. A portion of the gas is thoroughly delivered to a converter and liquefied through the output stream on the top of the tower. Then, this stream is sent to the top section of the distillation tower as an input feed stream and also as the reflux. The required work for a compression of the residue gas is less than the work, which is needed for the prevalent expander processes. Typically, the amount of energy in horsepower is less than that of the PR process with a recovery grade of 92%.

[0009] Another novel process called Cold Residue Recycle (CRR) is the rectified model of GSP process for achieving higher recovery efficiency. The stream path of the process is similar to that of GSP, except that the stream on the top of the tower in which a portion of residue gas is present, is sent back to a distillation tower as the extra return stream. The CRR process is used in high amounts of recovery.

[0010] Another process called Recycle Split Vapor (RSV) like CRR uses a feed vapor division process for providing a portion of ethane recovery in the tower. The return stream of the methane for the tower is supplied by extracting a small portion of the residual gas, which is recompressed and liquefied. The pressure of this stream is reduced to that of an entry section, which provides a portion of the feed, required for the top of the tower. The high pressure of this methane stream allows the gas in the top of the tower to be used for the process of liquefying and refrigerating. Hence, a portion of vapor feed can directly be delivered to the tower.

[0011] Yet another process called Recycle Split Vapor with Enrichment (RSVE) is the enhancement of the RSV process. Unlike RSV process, the return stream is extracted from the compressed residual gas and is mixed with the vapor stream feed before getting refrigerated and liquefied. Hence there is no need for a separate exchanger.

[0012] The development of the other NGL process based on a turbo expander leads to the recovery of increased NGL. This process uses a portion of the stream at the bottom of the distillation tower as a mixed refrigerant. The mixed refrigerant is partially or totally evaporated to provide the required refrigeration for refrigerating the input gas, which normally covers the external refrigeration. The vapor generated through this auto-refrigeration cycle is compressed again and sent back to the bottom of the tower. This vapor is used as a residue gas.

[0013] In an open-cycle refrigeration system, which aims to improve an efficiency and an economy of NGL recovery processes, a portion of a stream which contains liquid hydrocarbons is depleted from the lower parts of the distillation tower. This side stream warmed and expanded to create a two phase system for the separation of heavy hydrocarbon fluids and also to provide a vapor phase is sent back to the tower. The warm and expanded vapor returned back to the tower increases the concentration of methane and ethane. As a result of which, the temperature profile is decreased and separation efficiency is increased.

[0014] It is found that four configurations (GSP, CRR, RSV, and RSVE) are used to recover ethane for more than 90
percents. But the feed composition based on which CRR, RSV, RSVE were introduced contained 92.5% methane. In other words all the prior processes worked on lighter gases. The cited prior processes gave less emphasis on rich gases.

In the light of the foregoing discussions, there exists a need to provide a process for recovering natural gas liquids, which gives emphasis on rich gases. There also exists a need to provide a process for recovering the natural gas liquids to reduce the equipment cost and operational cost and increase in recovery efficiency. Furthermore there exists a need to provide a process for recovering the natural gas liquids and for proving an efficient refrigeration system resulting in a reduction of overall cost of the process.

The abovementioned shortcomings, disadvantages and problems are addressed herein and which will be understood by reading and studying the following specification.

OBJECT OF THE EMBODIMENTS

The primary object of the embodiments herein is to provide a method and a system for providing a required refrigeration load in a recovery of natural gas liquid so that the energy required by the system is reduced drastically.

Another object of the embodiments herein is to provide a method and a system for providing a required refrigeration load in a natural gas liquid recovery using an open-closed self-refrigeration system.

Yet another object of the embodiments herein is to provide a system and method for analyzing the configuration capability under circumstances in which the composition percentage is not stable and varied.

Yet another object of the embodiments herein is to provide a method and a system for providing a required refrigeration load in a natural gas liquid recovery to reduce the required energy of the overall system.

Yet another object of the embodiments herein is to provide a method and system for providing a refrigeration load, which is proportional to the variations of feed composition percentage.

Yet another object of the embodiments herein is to provide a method and a system for providing a required refrigeration load in a natural gas liquid recovery by providing a configuration, which performs on rich gases with high levels of liquid recovery.

Yet another object of the embodiments herein is to provide a method and a system for natural gas liquid recovery to reduce an energy consumption of the system.

Yet another object of the present invention is to provide a method and a system for natural gas liquid recovery to provide an inherent integrity resulting in reduction of numbers and volume of the applied process equipments.

Yet another object of the embodiments herein is to provide a method and a system for natural gas liquid recovery in which a distillation tower is used in the separation system thereby reducing the number of subsidiary systems and the refrigeration load to provide an optimal functioning of the configuration.

Yet another object of the embodiments herein is to provide a method and a system for natural gas liquid recovery in which the energy consumption is less than that of similar processes and systems.

These and other objects and advantages of the embodiments herein will become readily apparent from the following summary and the detailed description taken in conjunction with the accompanying drawings.

SUMMARY

The various embodiments herein provide a method and system for a process configuration with internal refrigeration for light gas and a process configuration with external refrigeration system for rich gas. The two processes are employed with a demethanizer column. The system and method provides a novel configuration which employs an open-closed self refrigeration system to provide a required refrigeration load. The system and method detects for a need for an external refrigeration unit or internal refrigeration unit based on the variations in the feed composition percentage. The system and method further provides an external refrigeration cycle using propane as a refrigerant. The configuration with internal refrigeration system utilizes a slip stream from or near the bottom of the demethanizer as a mixed refrigerant.

According to an embodiment, an internal refrigeration method for separating a residue gas from an input gas to recover a natural liquid gas through a self-refrigeration process comprising the steps of feeding an input gas into an internal refrigeration system. The input gas is condensed in a first multi-flow heat exchanger. An output of the first multi-flow heat exchanger is separated into a fluid stream and a gas stream using a first drum separator. The separated gas stream obtained from the first drum separator is divided into a first gas part and a second gas part. The separated fluid stream obtained from the first drum separator is divided into a first fluid part and a second fluid part. The first fluid part obtained from the first drum separator is passed to a middle section of a demethanizer column through a Joule-Thomson expansion valve for further fractionating. The second fluid part obtained from the first drum separator is passed to a top rectifying section in the demethanizer column through a second multi-flow heat exchanger and a first expansion valve to form a residue gas. The first gas part is passed to a work expander device. A gas stream output of the work expander device is passed to an area below a top rectifying section in the demethanizer column as an expander discharge. The second gas part is passed through the second multi-flow heat exchanger and a second expansion valve to the top rectifying section in the demethanizer column to form a reflux liquid. The residue gas from the top rectifying section of the demethanizer column is passed through the second multi-flow heat exchanger and the first multi-flow heat exchanger to a first compressor for further compression and wherein the first compressor compresses the residue gas using a work extracted from the expander device. A compressed residue gas output from the first compressor is passed to a second compressor for further compressing the residue gas. The compressed residue gas is passing further through a first air cooler. An output of the first cooler is forwarded as a gas refrigerant. The volatile components are stripped off from a liquid collected at a bottom portion of the demethanizer column by circulating the liquids from four liquid draw trays provided in the bottom portion of the demethanizer column through the first multi-flow heat exchanger and the second multi-flow heat exchanger and collecting back the liquids at the demethanizer column. The liquids are recovered from a bottom portion of the demethanizer column.
The step of stripping off the volatile components from the liquid collected at the bottom portion of the demethanizer column comprises passing a liquid drawn from a first liquid tray through the second multi-flow heat exchanger before being collected back at the demethanizer. A liquid drawn from a second liquid tray is passed through the second multi-flow heat exchanger before being collected back at the demethanizer. Wherein a direction of flow of the liquid from the first liquid tray through the second multi-flow heat exchanger and a direction of flow of the liquid from the second liquid tray through the second multi-flow heat exchanger are mutually opposite. A liquid drawn from a third liquid tray is passed through the first multi-flow heat exchanger before being collected back at the demethanizer. A liquid drawn from a fourth liquid tray is passed through the first multi-flow heat exchanger before being collected back at the demethanizer. Wherein a direction of flow of the liquid from the third liquid tray through the first multi-flow heat exchanger and a direction of flow of the liquid from the fourth liquid tray through the first multi-flow heat exchanger are mutually opposite.

The step of drawing liquid from the fourth liquid tray and passing through the multi-flow heat exchanger before being collected at the demethanizer column comprises passing a liquid drawn from the fourth tray through the first multi-flow heat exchanger. An output of the first multi-flow heat exchanger is passed to a second drum separator through a third expansion valve. A vapor output from the second drum is fed to a first stage of a third compressor. An output of the third compressor is passed to a second air cooler through a third multi-flow heat exchanger. An output of the second air cooler is forwarded to a third drum separator for dividing the output of the second air cooler into a vapor part and a liquid part. The liquid part obtained from the second air cooler is divided into a third liquid part and a fourth liquid part. The vapor part and the third liquid part obtained from the third drum separator are combined and forwarded to the demethanizer. The fourth liquid part obtained from the third drum separator is passed to the third multi-flow heat exchanger through a fourth expansion valve. An output of the third multi-flow heat exchanger is divided into a fifth liquid part and a sixth liquid part. The fifth liquid part from the output of the third multi-flow heat exchanger is passed to the second drum separator. The sixth liquid part from the output of the third multi-flow heat exchanger is fed to a fourth drum separator to obtain a vaporized liquid and a non-vaporized liquid. The vaporized liquid obtained from the fourth drum separator is forwarded to a second stage of the third compressor. The non-vaporized liquid from the fourth drum separator and the non-vaporized liquid from the second drum separator are combined and forwarded to the demethanizer. The input gas is a light gas containing a low amount of hydrocarbons that are converted into a natural gas liquid. The natural gas liquid has a lower volatility degree as compared to that of the residue gas.

According to an embodiment herein, a method of external refrigeration for separating a residue gas from an input gas to recover a natural liquid gas through a propane-refrigeration process comprising steps of feeding an input gas into an internal refrigeration system. The input gas is condensed in a first multi-flow heat exchanger. An output of the first multi-flow heat exchanger is separated into a liquid stream and a gas stream using a first drum separator. The separated gas stream obtained from the first drum separator is divided into a first gas part and a second gas part. The separated fluid stream obtained from the first drum separator is divided into a first fluid part and a second fluid part. The first fluid part obtained from the first drum separator is passed to a middle section of a demethanizer column through a Joule-Thomson expansion valve for further fractionating. The second fluid part obtained from the first drum separator is passed to a top rectifying section in the demethanizer column through a second multi-flow heat exchanger and a first expansion valve to form a residue gas. The first gas part is passed to a work expander device. A gas stream output of the work expander device is passed to an area below a top rectifying section in the demethanizer column as an expander discharge. The second gas part is passed through the second multi-flow heat exchanger and a second expansion valve to the top rectifying section in the demethanizer column to form a reflux liquid. The residue gas from the top rectifying section of the demethanizer column is passed through the second multi-flow heat exchanger and the first multi-flow heat exchanger to a first compressor for further compression and wherein the first compressor compresses the residue gas using a work extracted from the expander device. A compressed residue gas output from the first compressor is passed to a second compressor for further compressing the residue gas. The compressed residue gas is passed further through a first air cooler. An output of the first cooler is forwarded as a gas refrigerant. The volatile components are stripped off from a liquid collected at a bottom portion of the demethanizer column by circulating the liquids from four liquid draw trays provided in the bottom portion of the demethanizer column through the first multi-flow heat exchanger and the second multi-flow heat exchanger and collecting back the liquids at the demethanizer column. The liquids are recovered from a bottom portion of the demethanizer column. An external refrigeration process is provided using liquid propane.

The step of stripping off the volatile components from the liquid collected at the bottom portion of the demethanizer column comprises passing a liquid drawn from a first liquid tray through the second multi-flow heat exchanger before being collected back at the demethanizer. A liquid drawing from a second liquid tray is passed through the second multi-flow heat exchanger and a direction of flow of the liquid from the second liquid tray through the second multi-flow heat exchanger are mutually opposite. The separated fluid stream obtained from the first drum separator is divided into a first fluid part and a second fluid part. The first fluid part obtained from the first drum separator is passed to a middle section of a demethanizer column through a Joule-Thomson expansion valve for further fractionating. The second fluid part obtained from the first drum separator is passed to a top rectifying section in the demethanizer column through a second multi-flow heat exchanger and a first expansion valve to form a residue gas. The first gas part is passed to a work expander device. A gas stream output of the work expander device is passed to an area below a top rectifying section in the demethanizer column as an expander discharge. The second gas part is passed through the second multi-flow heat exchanger and a second expansion valve to the top rectifying section in the demethanizer column to form a reflux liquid. The residue gas from the top rectifying section of the demethanizer column is passed through the second multi-flow heat exchanger and the first multi-flow heat exchanger to a first compressor for further compression and wherein the first compressor compresses the residue gas using a work extracted from the expander device. A compressed residue gas output from the first compressor is passed to a second compressor for further compressing the residue gas. The compressed residue gas is passed further through a first air cooler. An output of the first cooler is forwarded as a gas refrigerant. The volatile components are stripped off from a liquid collected at a bottom portion of the demethanizer column by circulating the liquids from four liquid draw trays provided in the bottom portion of the demethanizer column through the first multi-flow heat exchanger and the second multi-flow heat exchanger and collecting back the liquids at the demethanizer column. The liquids are recovered from a bottom portion of the demethanizer column. An external refrigeration process is provided using liquid propane.
of a third compressor. An output liquid propane is passed from the second drum separator passed through the fourth expansion valve. An output liquid propane passed through the fourth expansion valve is divided into a first liquid propane part and a liquid propane part. The first liquid propane part output from the fourth expansion valve is led into a first multi-flow heat exchanger for providing required refrigeration for cooling the feed gas. The first liquid propane part output from the first multi-flow heat exchanger is forwarded to a third drum separator. The second liquid propane part output from the fourth expansion valve is led to the third drum separator directly through a sixth expansion valve. A vapor gas output of the third drum separator is forwarded into a second stage of the third compressor. A non vaporized liquid output from the third drum separator is fed to a fourth drum separator after passing the non vaporized liquid output from the third drum separator through a seventh expansion valve, the second multi-flow heat exchanger and the first multi-flow heat exchanger. A vaporized output from the fourth drum separator is passed to a first stage of the third compressor. A liquid propane output from the fourth drum separator is forwarded as an external refrigerant.

[0036] According to an embodiment herein, a system for separating a residue gas from an input gas to recover a natural liquid gas comprising a self refrigeration unit comprising an open-closed cycle of refrigeration and an external refrigeration unit. Wherein the self-refrigeration unit comprising an open-closed cycle of refrigeration provides a required refrigeration load and the external refrigeration unit provides a refrigeration load corresponding to variations in a feed composition percentage.

[0037] According to an embodiment herein, a process of internal refrigeration for separating a residue gas from an input gas to recover a natural liquid gas through self-refrigeration comprises steps of: feeding the input gas into the internal refrigeration system, condensing the input gas in a first multi-flow heat exchanger, separating a fluid stream and a gas stream by a first separator, dividing the gas stream as a first gas part and a second gas part and the fluid stream as a first fluid part and a second fluid part by the first separator, forming the residue gas by combining first gas part and second gas part, forming a liquid reflux by condensing the second gas part, producing the natural gas liquid by condensing the first fluid part.

[0038] According to an embodiment herein, the step of producing the natural gas liquid by condensing the first fluid part includes: decreasing temperature of the first fluid stream by an expansion valve, sending the first fluid stream to middle section of a distillation tower, increasing temperature of stream from middle section of the distillation tower by a second multi-flow heat exchanger, sending output stream of the expansion valve to the lower section of the distillation tower, producing a mixed refrigerant by combining one of the streams from a lower section of the distillation tower with a open cycle refrigerant, increasing the temperature of the mixed refrigerant by the first multi-flow heat exchanger by exchanging heat with the residue gas, decreasing temperature of output stream from the first multi-flow heat exchanger by a pressure breaker valve, increasing temperature of output stream from the pressure breaker valve by the first multi-flow heat exchanger by exchanging heat with the residue gas, separating unvaporized liquid from output gas from the first multi-flow heat exchanger by a first two phase separator, sending vaporized gas stream from the first two phase separator to first stage of a first two phase compressor, decreasing temperature of output stream of the first two phase compressor by a third multi-flow heat exchanger, partial conversion of output stream from the third multi-flow heat exchanger into liquid by a first air cooler, separating liquid from output stream of the first air cooler by a second stage separator, dividing output gas stream from the second stage separator as a first gas stream and a second second gas stream, increasing temperature of the first gas stream by the third multi-flow heat exchanger, dividing output gas stream from the third multi-flow heat exchanger as a first gas portion and a second gas portion, sending the first gas portion to second stage of the first two phase compressor, dividing the second gas portion into a gas stream and a fluid stream by a third two phase separator, compressing the gas stream from the third two phase separator by the second stage of the first two phase compressor, producing a vaporized refrigerant by combining the fluid stream from the third two phase separator with the liquid from the first two phase separator and producing the natural gas liquid by combining the vaporized refrigerant with the liquid from the second two phase separator in lower section of the distillation tower.

[0039] According to an embodiment herein, the step of forming a liquid reflux by condensing the second gas part includes: sub cooling the second gas part by the second multi-flow heat exchanger, reducing pressure and temperature of output of the second multi-flow heat exchanger by an expander and sending output of the expander to top of the distillation tower. The output of the expander is the liquid reflux.

[0040] According to an embodiment herein, the step of forming the residue gas by combining first gas part and second fluid part includes: reducing pressure and temperature of first gas part and second fluid part by an expander, sending output of the expander to the upper section of the distillation tower, increasing the temperature of output of the first expander through a second multi-flow heat exchanger and first multi-flow heat exchanger by exchanging heat with the input gas, increasing temperature and pressure of the output gas from the first multi-flow heat exchanger by compressing in a first compressor and reducing the temperature of the output gas from the first compressor by a second air cooler to produce a residue gas, wherein the residue gas is the closed cycle refrigerant.

[0041] According to an embodiment herein, the input gas is light gas containing less amounts of hydrocarbons and is turned into natural gas liquid.

[0042] According to an embodiment herein, the natural gas liquid is having lower volatility degree as compared to the residue gas.

[0043] According to an embodiment herein, the distillation tower is equipped with four liquid draw trays in the lower section to provide heat to the tower for stripping volatile components off from the liquid product.

[0044] According to an embodiment herein, a process of external refrigeration for separating a residue gas from an input gas to recover a natural liquid gas through propane-refrigeration comprising the steps of: distributing the propane refrigerant for the first multi-flow heat exchanger, feeding the input gas into the external refrigeration system, condensing the input gas in a first multi-flow heat exchanger, separating a fluid stream and a gas stream by a first separator, dividing the gas stream as a first gas part and a second gas part and the fluid stream as a first fluid part and a second fluid part by the first
separator, forming the residue gas by combining first gas part and second fluid part, forming a liquid reflux by condensing the second gas part, producing the natural gas liquid by condensing the first fluid part.

[0045] According to an embodiment herein, the step of producing the natural gas liquid by condensing the first fluid part includes: decreasing temperature of the first fluid stream by an expansion valve, sending the first fluid stream to middle section of a distillation tower, increasing temperature of stream from middle section of the distillation tower by a second multi-flow heat exchanger by exchanging heat with the propane refrigerant, sending output stream of the expansion valve to the lower section of the distillation tower, increasing the temperature of the stream from lower section of the distillation tower by the first multi-flow heat exchanger by exchanging heat with the propane refrigerant, decreasing temperature of output stream from the first multi-flow heat exchanger by a pressure breaker valve, increasing temperature of output stream from the pressure breaker valve by the first multi-flow heat exchanger by exchanging heat with the propane refrigerant, separating unvaporized liquid from output gas from the first multi-flow heat exchanger by a first two phase separator, sending vaporized gas stream from the first two phase separator to first stage of a first two phase compressor, decreasing temperature of output stream of the first two phase compressor by a third multi-flow heat exchanger by exchanging heat with the propane refrigerant, partial conversion of output stream from the third multi-flow heat exchanger into liquid by a first air cooler, separating liquid from output stream of the first air cooler by a second two stage separator, dividing output gas stream from the second two stage separator as a first gas stream and a second gas stream, increasing temperature of the first gas stream by the third multi-flow heat exchanger by exchanging heat with the propane refrigerant, dividing output gas stream from the third multi-flow heat exchanger as a first gas portion and a second gas portion, sending the first gas portion to second stage of the first two phase compressor, dividing the second gas portion into a gas stream and a fluid stream by a third two phase separator, compressing the gas stream from the third two phase separator by second stage of the first two phase compressor, producing a vaporized refrigerant by combining the fluid stream from the third two phase separator with the liquid from the first two phase separator and producing the natural gas liquid by combining the vaporized refrigerant with the liquid from the second two phase separator in lower section of the distillation tower.

[0046] According to an embodiment herein, the step of forming a liquid reflux by condensing the second gas part includes: sub cooling the second gas part by the second multi-flow heat exchanger, reducing pressure and temperature of output of the second multi-flow heat exchanger by an expander and sending output of the expander to top of the distillation tower. The output of the expander is the liquid reflux.

[0047] According to an embodiment herein, the step of forming the residue gas by combining first gas part and second fluid part includes: reducing pressure and temperature of first gas part and second fluid part by an expander, sending an output of the expander to the upper section of the distillation tower, increasing the temperature of output of the first expander through a second multi-flow heat exchanger and first multi-flow heat exchanger by exchanging heat with the input gas, increasing the temperature and the pressure of the output gas from the first multi-flow heat exchanger by compressing in a first compressor and reducing the temperature of the output gas from the first compressor by a second air cooler to produce a residue gas, wherein the residue gas is the closed cycle refrigerant.

[0048] These and other aspects of the embodiments herein will be better appreciated and understood when considered in conjunction with the following description and the accompanying drawings. It should be understood, however, that the following descriptions, while indicating preferred embodiments and numerous specific details thereof, are given by way of illustration and not of limitation. Many changes and modifications may be made within the scope of the embodiments herein without departing from the spirit thereof, and the embodiments herein include all such modifications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0049] The other objects, features and advantages will occur to those skilled in the art from the following description of the preferred embodiment and the accompanying drawings in which:

[0050] FIG. 1 illustrates a block flow diagram for gas and liquid streams in a process configuration with the self-refrigeration system, according to an embodiment herein.

[0051] FIG. 2 illustrates a graph indicating the composite curves of a heat exchanger MSHX-1 for a process configuration with the self-refrigeration system, according to an embodiment herein.

[0052] FIG. 3 illustrates a graph indicating the composite curves of a heat exchanger MSHX-2 for a process configuration with the self-refrigeration system, according to an embodiment herein.

[0053] FIG. 4 illustrates a block flow diagram for gas and liquid streams in a process configuration with the external refrigeration system, according to an embodiment herein.

[0054] FIG. 5 illustrates a graph indicating the composite curves of the heat exchanger MSHX-1 showing the relationship between a heat flow and a temperature for a process configuration with external refrigeration system, according to an embodiment herein.

[0055] FIG. 6 illustrates a graph indicating the composite curves of the heat exchanger MSHX-1 showing the relationship between an inlet feed gas and a required refrigeration flow for a process configuration with external refrigeration system, according to an embodiment herein.

[0056] FIG. 7 illustrates a graph indicating the composite curves of the heat exchanger MSHX-1 showing the relationship between a heat flow and a temperature for a feed 1 in a process configuration with self-refrigeration system, according to an embodiment herein.

[0057] FIG. 8 illustrates a graph indicating the composite curves of the heat exchanger MSHX-2 showing the relationship between a heat flow and a temperature for a feed 1 in a process configuration with self-refrigeration system, according to an embodiment herein.

[0058] FIG. 9 illustrates a graph indicating the composite curves of the heat exchanger MSHX-1 showing the relationship between a heat flow and a temperature for a feed 6 in a process configuration with self-refrigeration system, according to an embodiment herein.

[0059] FIG. 10 illustrates a graph indicating the composite curves of the heat exchanger MSHX-2 showing the relation-
ship between a heat flow and a temperature for a feed in a process configuration with self-refrigeration system, according to an embodiment herein.

Although the specific features of the embodiments herein are shown in some drawings and not in others. This is done for convenience only as each feature may be combined with any or all of the other features in accordance with the embodiments herein.

DETAILED DESCRIPTION OF THE EMBODIMENTS

In the following detailed description, a reference is made to the accompanying drawings that form a part hereof, and in which the specific embodiments that may be practiced is shown by way of illustration. These embodiments are described in sufficient detail to enable those skilled in the art to practice the embodiments and it is to be understood that the logical, mechanical and other changes may be made without departing from the scope of the embodiments. The following detailed description is therefore not to be taken in a limiting sense.

The various embodiments herein provide a method and system for a process configuration with internal refrigeration for a light gas and a process configuration with external refrigeration system for a rich gas. The two processes are employed with the separation methods using a demethanizer column. The configuration with internal refrigeration system utilizes a slip stream from or near the bottom of the demethanizer as a mixed refrigerant.

According to an embodiment herein, a process of internal refrigeration for separating a residue gas from an input gas to recover a natural liquid gas through a self-refrigeration comprising the steps of, feeding an input gas into the internal refrigeration system, condensing the input gas in a first multi-flow heat exchanger, separating a fluid stream and a gas stream by a first separator, dividing the gas stream as a first gas part and a second gas part and the fluid stream as a first fluid part and a second fluid part by the first separator, forming the residue gas by combining first gas part and second fluid part, forming a liquid reflux by condensing the second gas part, producing the natural gas liquid by condensing the first fluid part.

According to an embodiment herein, the step of producing the natural gas liquid by condensing the first fluid part includes: decreasing a temperature of the first fluid stream by an expansion valve, sending the first fluid stream to a middle section of a distillation tower, increasing a temperature of a stream from a middle section of the distillation tower by a second multi-flow heat exchanger, sending an output stream of the expansion valve to the lower section of the distillation tower, producing a mixed refrigerant by combining one of the streams from a lower section of the distillation tower with a open cycle refrigerant, increasing the temperature of the mixed refrigerant by the first multi-flow heat exchanger by exchanging the heat with the residue gas, decreasing a temperature of an output stream from the first multi-flow heat exchanger by a pressure breaker valve, increasing a temperature of an output stream from the pressure breaker valve by the first multi-flow heat exchanger by exchanging the heat with the residue gas, separating non-vaporized liquid from an output gas from the first multi-flow heat exchanger by a first two phase separator, sending a vaporized gas stream from the first two phase separator to a first stage of a first two phase compressor, decreasing a temperature of an output stream of the first two phase compressor by a third multi-flow heat exchanger, partial conversion of an output stream from the third multi-flow heat exchanger into a liquid by a first air cooler, separating a liquid from an output stream of the first air cooler by a second two stage separator, dividing an output gas stream from the second two stage separator as a first gas stream and a second a second gas stream, increasing a temperature of the first gas stream by the third multi-flow heat exchanger, dividing an output gas steam from the third multi-flow heat exchanger as a first gas portion and a second gas portion, sending the first gas portion to a second stage of the first two phase compressor, dividing the second gas portion into a gas stream and a fluid stream by a third two phase separator, compressing the gas stream from the third two phase separator by a second stage of the first two phase compressor, producing a vaporized refrigerant by combining the fluid stream from the third two phase separator with the liquid from the first two phase separator and producing the natural gas liquid by combining the vaporized refrigerant with the liquid from the second two phase separator in lower section of the distillation tower.

According to an embodiment herein, the step of forming a liquid reflux by condensing the second gas part includes: sub cooling the second gas part by the second multi-flow heat exchanger, reducing a pressure and a temperature of an output of the second multi-flow heat exchanger by an expander and sending an output of the expander to a top portion of the distillation tower. The output of the expander is a reflux liquid.

According to an embodiment herein, the step of forming the residue gas by combining a first gas part and a second fluid part includes: reducing a pressure and a temperature of a first gas part and a second fluid part by an expander, sending an output of the expander to the upper section of the distillation tower, increasing the temperature of output of the first expander through a second multi-flow heat exchanger and first multi-flow heat exchanger by exchanging heat with the input gas, increasing a temperature and a pressure of the output gas from the first multi-flow heat exchanger by compressing in a first compressor and reducing the temperature of the output gas from the first compressor by a second air cooler to produce a residue gas, wherein the residue gas is the closed cycle refrigerant.

According to an embodiment herein, the input gas is light gas containing less amounts of hydrocarbons that are turned into natural gas liquid.

According to an embodiment herein, the natural gas liquid is having lower volatility degree as compared to the residue gas.

According to an embodiment herein, the distillation tower is equipped with four liquid draw trays in a lower section to provide a heat to the tower for stripping off the volatile components from the liquid product.

According to an embodiment herein, a process of external refrigeration for separating a residue gas from an input gas to recover a natural liquid gas through a propane refrigeration comprising the steps of: distributing the propane refrigerant for the first multi-flow heat exchanger, feeding the input gas into the external refrigeration system, condensing the input gas in a first multi-flow heat exchanger, separating a fluid stream and a gas stream by a first separator, dividing the gas stream as a first gas part and a second gas part and the fluid stream as a first fluid part and a second fluid part by the first separator, forming the residue gas by combining first gas part and second fluid part.
and second fluid part, forming a liquid reflux by condensing the second gas part, producing the natural gas liquid by condensing the first fluid part.

According to an embodiment herein, the step of producing the natural gas liquid by condensing the first fluid part includes: decreasing a temperature of the first fluid stream by an expansion valve, sending the first fluid stream to a middle section of a distillation tower, increasing a temperature of a stream from the middle section of the distillation tower by a second multi-flow heat exchanger by exchanging the heat with the propane refrigerant, sending an output stream of the expansion valve to the lower section of the distillation tower, increasing the temperature of the stream from a lower section of the distillation tower by the first multi-flow heat exchanger by exchanging the heat with the propane refrigerant, decreasing a temperature of an output stream from the first multi-flow heat exchanger by a pressure breaker valve, increasing a temperature of an output stream from the pressure breaker valve by the first multi-flow heat exchanger by exchanging the heat with the propane refrigerant, separating non-vaporized liquid from an output gas from the first multi-flow heat exchanger by a first two phase separator, sending a vaporized gas stream from the first two phase separator to a first stage of a first two phase compressor, decreasing a temperature of an output stream of the first two phase compressor by a third multi-flow heat exchanger by exchanging the heat with the propane refrigerant, partial conversion of an output stream from the third multi-flow heat exchanger into a liquid by a first air cooler, separating a liquid from an output stream of the first air cooler by a second stage separator, dividing an output gas stream from the second stage separator as a first gas stream and a second gas stream, increasing a temperature of the first gas stream by the third multi-flow heat exchanger by exchanging the heat with the propane refrigerant, dividing an output gas stream from the third multi-flow heat exchanger as a first gas portion and a second gas portion, sending the first gas portion to a second stage of the first two phase compressor, dividing the second gas portion into a gas stream and a liquid stream by a third two phase separator, compressing the gas stream from the third two phase separator with the liquid from the first two phase separator and producing the natural gas liquid by combining the vaporized refrigerant with the liquid from the second two phase separator in lower section of the distillation tower.

According to an embodiment herein, the step of forming a liquid reflux by condensing the second gas part includes: sub cooling the second gas part by the second multi-flow heat exchanger, reducing a pressure and a temperature of an output of the second multi-flow heat exchanger by an expander and sending an output of the expander to a top of the distillation tower. The output of the expander is the liquid reflux.

According to an embodiment herein, the step of forming the residue gas by combining a first gas part and a second fluid part includes: reducing a pressure and a temperature of the first gas part and a second fluid part by an expander, sending an output of the expander to the upper section of the distillation tower, increasing the temperature of an output of the first expander through a second multi-flow heat exchanger and a first multi-flow heat exchanger by exchanging the heat with the input gas, increasing a temperature and a pressure of the output gas from the first multi-flow heat exchanger by compressing in a first compressor and reducing the temperature of the output gas from the first compressor by a second air cooler to produce a residue gas, wherein the residue gas is the closed cycle refrigerant.

Fig. 1 is a stream diagram of a process configuration with the internal refrigeration system, according to an embodiment herein. With respect to Fig. 1, a feed gas comprising a pretreated and clean natural gas or refinery gas stream is introduced into the illustrated process through an inlet stream Feed Gas at a temperature of about 37.7°C and an elevated pressure of about 63 bars. The stream is cooled in the multi stream heat exchanger MSHX-1 to reduce the temperature of the stream to about ±32.5°C. The output stream 1 from MSHX-1 is passed to the flash drum D-1 for a separation of the condensed liquid, if any. A portion of the liquid 4 is introduced into the middle of demethanizer column for further fractionation. A J-T valve decreases its temperature to about ±56°C before entering to the tower. Another portion, stream 3, is expanded through the expansion valve VLV-3 and fed to the demethanizer. The outlet vapor stream 2 from the drum D-1 is divided into two portions, the main portion 2 and the remaining portion 6. The main portion 2 which is about 60%, is expanded through a work-expansion turbine Ex-1 prior to entering the demethanizer right below the top rectifying section as an expander discharge 8. The remaining vapor portion 6 is cooled to substantially condensation, and in most cases sub-cooling, to approximately ±95°C via MSHX-2. This sub-cooled liquid stream 9 is expanded through the expansion valve VLV-2 and fed to top of the demethanizer as reflux liquid.

The demethanizer operated at approximately 25 bars is a distillation column containing conventional kinds of trays applied in the demethanizer towers. The demethanizer is equipped with four liquid draw trays in the lower section of the column to provide a heat to the column for stripping off the volatile components from the bottom liquid product. This is accomplished via the use of two multi stream heat exchangers MSHX-1, MSHX-2. The liquids drawn from the side of the demethanizer 14& 16, and 18& 20 are passed to the MSHX-2 and MSHX-1 at ±54, ±53, ±36 & ±16.5°C respectively, and exit as streams 15&17, and 19 & 37 at approximately ±42, ±41, ±24 & ±25°C respectively, prior to returning to the demethanizer.

The residue gas 7 exiting the upper portion of the demethanizer is fed to the MSHX-2 exchanger, providing refrigeration for condensing/supply cooling the vapor split stream 6 and sub cooling the liquid stream 3 from the drum D-1. The residue gas 10 exiting the MSHX-2 is further warmed to near the feed gas temperature via MSHX-1. The warmed residue gas 11 leaving the MSHX-1 at approximately 34°C is sent to the suction of the expander compressor C-1, where it is compressed to 29 bars by utilizing a work extracted from the expander Ex-1. Depending upon the needed delivery pressure, a residue gas compressor C-2 may be needed to further compress the residue gas stream 12 from the compressor C-1, followed by an air cooler AC-1, prior to its final delivery at 62 bar.

In this configuration, the refrigeration provided by the residue gas from the demethanizer, turbo expander Ex-1 and the side liquid draws is not sufficient to achieve a high level of ethane recovery. So, a self-refrigeration system is applied. Stream 20, the open cycle refrigerant, is withdrawn from the chimney tray of the demethanizer column; the result-
ing mixed refrigerant is preferentially fed to the MSHX-1 for sub cooling prior to being expanded through the expansion device VLV-1 at 9 bar. The expanded stream 21 is directed back to the MSHX-1 providing an indirect heat exchange with the feed gas stream and thereafter fed to the suction knockout drum D-2 where an unvaporized liquid in any, is separated while the refrigerant is used to cool the inlet gas stream. The vapor stream 24 produced in the knockout drum D-2 is withdrawn from the top thereof and fed to a first stage of a two-stage recycle compressor C-3. The re-pressurized gas stream 28 exiting compressor C-3 is cooled in MSHX-3 to 89°C, and then the output 29 of the heat exchanger MSHX-3 is fed to the air cooler AC-2 resulting in a partial condensation. The partially condensed product 30 exiting the cooler AC-2 is introduced into separator D-3 where condensed liquid is separated. A portion of the output liquid stream 34 withdrawn from separator D-3 (representing closed cycle refrigerant) is used as a refrigerant in the heat exchanger MSHX-3. In fact this portion provides a part of the required refrigeration in the condensation section of open-cycle refrigeration system. The flow rate of Stream 34, pressure drop in the VLV-4 expansion device and the temperature of stream 35 are parameters, which should be adjusted, based on the open refrigeration cycle performance. Also these three parameters affect the air cooler performance and its design condition. Consequently a tradeoff between the compressors shaft work and condensation costs (fixed and operating costs related to the air cooler) will determine their optimum value.

[0078] A portion of the outlet stream 35 from MSHX-3 flows to D-4 knockout drum as the closed cycle separator. The vapor product 27 of D-4 is introduced into the second stage of the compressor C-3. After an indirect heat exchange with one or more process streams, the heated open and closed refrigerant is preferably combined for simplicity and introduced into suction knockout drum D-2 where the vaporized refrigerant is separated. The vapor stream 24 is then introduced to the first stage recycle compressor C-3. The pressure of a liquid product drawn from D-4 is increased by the P-2 pump, next this stream, 36 is mixed with stream 26 (Separator D-2 liquid product). Finally stream 37 is introduced to the bottom of the demethanizer column (stream 37). The pressure, temperature and flow rate of the process streams are presented in Table 1.

### TABLE 1

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Pressure (bar)</th>
<th>Flow rate (kmole/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Gas 37.78</td>
<td>63.00</td>
<td>14942.28</td>
</tr>
<tr>
<td>1</td>
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<td>63.00</td>
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<td>15</td>
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<td>63.00</td>
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[0079] FIG. 2 illustrates a graph indicating the composite curves of a heat exchanger MSHX-1 for a process configuration with the self-refrigeration system, according to an embodiment herein while FIG. 3 illustrates a graph indicating the composite curves of a heat exchanger MSHX-2 for a process configuration with the self-refrigeration system, according to an embodiment herein. In this configuration, the feed will get cooled off through MSHX-1 and MSHX-2 heat exchangers, in two stages. In other words, two heat exchangers are considered for two types of process cold streams: Firstly, those cold streams whose temperature is extremely low (the streams which exit from the upper section of the tower) and cool streams whose temperature is relatively higher (the streams which exit from the lower sections of the tower). This method enjoys two advantages: firstly, it causes the process cold streams and refrigeration cycles to optimally be recovered. And secondly, it causes the combined curves to be in their most optimal position, which is an evidence of optimum functioning of multi-flow heat exchangers. It is worth noting that setting the operating conditions is highly important in the unit, because they are able to strongly influence the function of multi-flow heat exchangers while the increase in the number of heat exchangers leads to larger optimization problem. Although a configuration with a multi-flow heat exchanger can be designed, but a temperature control of cold streams will be limited to achieve the optimum point of efficiency.

[0080] The form of combined curves is an important factor illustrating the efficiency of multi-flow heat exchangers. Pinch point in this curve illustrates the extreme proximity of the curves. The structural capabilities of the heat exchanger determine the lowest allowed temperature difference between cool and hot curves. The lowest temperature difference in this curve is considered to be 2°C.

[0081] MSHX-1 exchanger decreases the temperature of the feed to 300°C. FIG. 2 illustrates the combined curve of this
The required refrigeration in this apparatus is provided through two refrigeration resources (open cycle and side streams of distillation tower). This apparatus applies warmer cool fluid process streams, and prepares feed stream for entering the MSHX-2 exchanger. MSHX-2 uses the stream number 7 as the coolest process stream. FIG. 3, illustrates the combined curve of this apparatus.

The required refrigeration in this apparatus is provided through two refrigeration resources (open cycle and side streams of distillation tower). This apparatus applies warmer cool fluid process streams, and prepares feed stream for entering the MSHX-2 exchanger. MSHX-2 uses the stream number 7 as the coolest process stream. FIG. 3, illustrates the combined curve of this apparatus.

FIG. 4 is a stream diagram of a process configuration with the external refrigeration system, according to an embodiment herein. With respect to FIG. 4, a feed gas comprising a pretreated and clean natural gas or refinery gas stream is introduced into the illustrated process through an inlet stream. The feed gas is at a temperature of about 37.7°C and an elevated pressure of about 63 bars. This stream is cooled in the multi-stream heat exchanger MSHX-1 to reduce the temperature of the stream to about -29°C. The output stream 1 from MSHX-1 follows to the flash drum D-1 for separation of the condensed liquid, if any. A portion of the liquid 4 is introduced into the middle of demethanizer column for further fractionation. A J-T valve decreases its temperature to about -47.65°C before entering to the tower. Another portion, stream 3, is expanded through the expansion valve VLV-3 and fed to the demethanizer.

The multi-stream heat exchanger MSHX-1, MSHX-2. The side draw liquids 14, 16, and 18, 20 to enter the MSHX-2 and MSHX-1 at -55.29, -51.88, -31.34 & -7.7°C, respectively, and exit as streams 15, 17, 19 & 21 at approximately -43, -38, -20 & 35°C, respectively, prior to returning to the demethanizer.

The residue gas 7 exiting the upper portion of the demethanizer is fed to the MSHX-2 exchanger, providing refrigeration for condensing/sub-cooling the vapor split stream 6 and sub-cooling the liquid stream 3 from the drum D-1.

Material balance for the processes illustrated in the FIG. 4

<table>
<thead>
<tr>
<th>Stream Number</th>
<th>Temperature (°C)</th>
<th>Pressure (bar)</th>
<th>Flow rate (kmole/hr)</th>
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</thead>
<tbody>
<tr>
<td>Feed Gas</td>
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<td>14942.28</td>
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TABLE 2-continued

Material balance for the processes illustrated in the FIG. 4

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<tr>
<th>Stream Number</th>
<th>Temperature (°C)</th>
<th>Pressure (bar)</th>
<th>Flow rate (kmole/hr)</th>
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FIG. 5 illustrates a graph indicating the composite curves of the heat exchanger MSHEX-1 showing the relationship between a heat flow and a temperature for a process configuration with external refrigeration system, according to an embodiment herein. The form of combined curves is an important factor illustrating the efficiency of multi-flow heat exchangers. Pinch point in this curve illustrates the extreme proximity of the curves. The structural capabilities of the heat exchanger determine the lowest allowed temperature difference between cool and hot curves. A comparison between FIGS. 3&5 shows that the multi stream heat exchangers in the FIG. 1 process are more efficient than the ones, which used in the process with external refrigeration system (FIG. 4).

FIG. 6 illustrates a graph indicating the composite curves of the heat exchanger MSHEX-1 showing the relationship between an inlet feed gas and a required refrigeration flow for a process configuration with external refrigeration system, according to an embodiment herein. With respect to FIG. 6, the required power increases linearly. Also the power required for increasing the pressure of the residue gas and also the power of AC-1 fan air cooler decreases, as the feed becomes richer, because the richer is the gas, the more refrigeration it will need and thereupon, the air stream discharge should be increased in air coolers. The power of needed fan in external refrigeration system will be more due to the difference in refrigerant discharge in internal and external systems. Mutually, the power of required fan will decrease as the gas becomes richer, but the temperature of stream entering AC-1 in FIG. 1 will be higher than that of FIG. 4, so more air stream is needed in this process. In all the cases, ethane recovery was considered constant and equal in both of the configurations. So the least proximity temperature in MSHEX-1 and MSHEX-2 will be 2°C. According to tables 4 and 5, as the fraction Deuterium increases in the feed, ethane recovery level will decrease. In the mixtures which have high amounts of methane (more than 80 percent), the process function will be desirable, and higher levels of ethane recovery can be achieved as the compressor of the auto-refrigeration systems consumes lower power. And the power of residue gas compressor increases due to the increase of methane amount. In the mixtures containing high amounts of C2+ and hydrogen, the system’s required by auto-refrigeration system (FIG. 1) increases by the decrease in methane fraction, and the required power for residue gas compressor decreases. Though, the level of ethane and methane recovery can be controlled in amount of +490. Although the least proximity temperature in the [2, 2.5] range was made fixed, but the form of combined curves changes depending on the combination of the feed.

TABLE 4

Overall performance of the configuration

<table>
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<tr>
<th>Prior Art(s)</th>
<th>Present invention</th>
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<tr>
<td>% Ethane recovery</td>
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<td>% Propane recovery</td>
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TABLE 5

Overall performance of the process for the different feed compositions (FIG. 1)

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<th>Feed 4</th>
<th>Feed 5</th>
<th>Feed 6</th>
</tr>
</thead>
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<tr>
<td>% Ethane recovery</td>
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<td>93.91</td>
<td>93.36</td>
<td>91.41</td>
<td>92.41</td>
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<tr>
<td>% Propane recovery</td>
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<td>99.95</td>
<td>99.48</td>
<td>99.40</td>
<td>99.87</td>
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<tr>
<td>% Methane recovery</td>
<td>0.99</td>
<td>99.13</td>
<td>99.12</td>
<td>98.95</td>
<td>98.55</td>
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<tr>
<td>MSHEX1 minimum temperature approach °C</td>
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<td>2.00</td>
<td>2.00</td>
<td>2.11</td>
<td>2.00</td>
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<tr>
<td>MSHEX2 minimum temperature approach °C</td>
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<td>2.00</td>
<td>2.00</td>
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<tr>
<td>Self-refrigeration compression, kW</td>
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<td>3095.82</td>
<td>3475.36</td>
<td>4105.62</td>
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<tr>
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<td>9334.59</td>
<td>9213.96</td>
<td>9042.51</td>
<td>8608.91</td>
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Overall performance of the process for the different feed compositions (FIG. 1)

<table>
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<tr>
<th>Feed</th>
<th>Duty of refrigeration system air cooler, kW</th>
<th>Duty of residue gas air cooler, kW</th>
<th>Heat flow of Feed stream, kW</th>
<th>Heat flow of Liquid Product, kW</th>
<th>Heat flow of Gas Product, kW</th>
<th>Fan power in the residue gas air cooler, kW</th>
<th>Fan power in the air cooler of refrigeration system, kW</th>
<th>Overall required power, kW</th>
</tr>
</thead>
<tbody>
<tr>
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<td>334912.74</td>
<td>-81909.12</td>
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<td>55.06</td>
<td>12192.22</td>
</tr>
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</tr>
<tr>
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<td>55.06</td>
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</tr>
<tr>
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<td>79.86</td>
<td>55.06</td>
<td>12192.22</td>
</tr>
</tbody>
</table>

TABLE 6 Overall performance of the process for the different feed compositions (FIG. 4)

| Feed | % Ethane recovery | % Propane recovery | % Methane recovery | MSHX1 minimum temperature approach °C | MSHX2 minimum temperature approach °C | Propane refrigeration, kW | Residue gas compression, kW | Duty of refrigeration system air cooler, kW | Duty of residue gas air cooler, kW | Heat flow of Feed stream, kW | Heat flow of Liquid Product, kW | Heat flow of Gas Product, kW | Fan power in the residue gas air cooler, kW | Fan power in the air cooler of refrigeration system, kW | Overall required power, kW |
|------|------------------|-------------------|-------------------|---------------------------------------|---------------------------------------|--------------------------|-----------------------------|------------------------------------------|---------------------------------|-------------------------------|----------------------------------|-------------------------------|--------------------------------|------------------------------------------|------------------------------------------|-----------------------------|
| 1    | 94               | 93.89             | 93.52             | 91.6                                  | 92.5                                  | 90.15                     | 9783.394                    | 9442.384                                 | 9314.823                       | 9020.75                         | 8763.665                        | 8591.18                      | 5297.368                                    | 4852.752                                 | 5078.086                                  |
| 2    | 99.5             | 99.45             | 99.5              | 99.38                                 | 99.7                                  | 99.55                     | 2972.356                    | 3839.229                                 | 4152.029                       | 4272.29                         | 4852.752                        | 5078.086                      | 214.19                                    | 2.16                                      |                                           |
| 3    | 99.5             | 99.45             | 99.5              | 99.38                                 | 99.7                                  | 99.55                     | 2972.356                    | 3839.229                                 | 4152.029                       | 4272.29                         | 4852.752                        | 5078.086                      | 214.19                                    | 2.16                                      |                                           |
| 4    | 99.5             | 99.45             | 99.5              | 99.38                                 | 99.7                                  | 99.55                     | 2972.356                    | 3839.229                                 | 4152.029                       | 4272.29                         | 4852.752                        | 5078.086                      | 214.19                                    | 2.16                                      |                                           |
| 5    | 99.5             | 99.45             | 99.5              | 99.38                                 | 99.7                                  | 99.55                     | 2972.356                    | 3839.229                                 | 4152.029                       | 4272.29                         | 4852.752                        | 5078.086                      | 214.19                                    | 2.16                                      |                                           |
| 6    | 99.5             | 99.45             | 99.5              | 99.38                                 | 99.7                                  | 99.55                     | 2972.356                    | 3839.229                                 | 4152.029                       | 4272.29                         | 4852.752                        | 5078.086                      | 214.19                                    | 2.16                                      |                                           |

[0091] As it was expected, the heavier is the gas, the more refrigeration does it need. Also, changes in specifications of the process as the combination of the feed varies can be followed through these two tables. Therefore the types of configurations can be compared accurately (according to FIGS. 1 and 4). As it was said previously, the process in FIG. 4 was designed, so a precise comparison can be done between the function of internal and external refrigeration system for
the proposed configuration. According to operating conditions (temperature, pressure and discharge) it can be assumed that the size of separation equipments are the same in both of the configurations. And also MSHX-2 and MSHX-1 exchangers in FIG. 4, have one more path comparing to FIG. 1. Consequently it can be said that the constant investment costs for these two equipments are equal. AC-2 air coolers are in the same size in both configurations (UA is the same in both of the configurations), C-3 is a two-stage compressor in FIG. 1, whilst in FIG. 4 it is a three-stage compressor. There are three (D-2, D-3, D-4) in both of the configurations, but they are bigger in FIG. 4 than in FIG. 1. So the number of equipments is equal in both external and internal refrigeration systems but their size is smaller in internal system. Considering what mentioned above, in circumstances in which the feed combination changes, operating costs can be a determining factor in comparison between the function of FIGS. 1 and 4.

[0092] FIG. 7 illustrates a graph indicating the composite curves of the heat exchanger MSHX-1 showing the relationship between a heat flow and a temperature for a feed 1 in a process configuration with self-refrigeration system, according to an embodiment herein. The form of combined curves is an important factor illustrating the efficiency of multi-flow heat exchangers. Pinch point in this curve illustrates the extreme proximity of the curves. The structural capabilities of the heat exchanger determine the lowest allowed temperature difference between cool and hot curves

[0093] FIG. 8 illustrates a graph indicating the composite curves of the heat exchanger MSHX-2 showing the relationship between a heat flow and a temperature for a feed 1 in a process configuration with self-refrigeration system, according to an embodiment herein. The form of combined curves is an important factor illustrating the efficiency of multi-flow heat exchangers. Pinch point in this curve illustrates the extreme proximity of the curves. The structural capabilities of the heat exchanger determine the lowest allowed temperature difference between cool and hot curves

[0094] FIG. 9 illustrates a graph indicating the composite curves of the heat exchanger MSHX-1 showing the relationship between a heat flow and a temperature for a feed 6 in a process configuration with self-refrigeration system, according to an embodiment herein. The form of combined curves is an important factor illustrating the efficiency of multi-flow heat exchangers. Pinch point in this curve illustrates the extreme proximity of the curves. The structural capabilities of the heat exchanger determine the lowest allowed temperature difference between cool and hot curves

[0095] FIG. 10 illustrates a graph indicating the composite curves of the heat exchanger MSHX-2 showing the relationship between a heat flow and a temperature for a feed 6 in a process configuration with self-refrigeration system, according to an embodiment herein. The form of combined curves is an important factor illustrating the efficiency of multi-flow heat exchangers. Pinch point in this curve illustrates the extreme proximity of the curves. The structural capabilities of the heat exchanger determine the lowest allowed temperature difference between cool and hot curves

[0096] The embodiments herein provide a method and a system for providing required refrigeration load in a natural gas liquid recovery. The method and system provides required refrigeration load in a natural gas liquid recovery using an open-closed self-refrigeration system. The system and method for analyzing the configuration capability under circumstances in which the composition percentage is not stable and varies is provided. The process configuration provides required refrigeration load in a natural gas liquid recovery to reduce the required energy of the overall system. The method and system investigates the need of the unit to refrigeration proportional to the variations in feed composition percentage. The process configuration uses least number of multi-stream converters, further leading to the integration of the process operation. The process configuration here in performs on rich gases with high levels of liquid recovery. The presented process configuration reduces over all consumed energy of the system. The method and system for natural gas liquid recovery provides inherent integrity resulting in reduction of numbers and volume of the applied process equipments.

[0097] The foregoing description of the specific embodiments will so fully reveal the general nature of the embodiments herein that others can, by applying current knowledge, readily modify and/or adapt for various applications such specific embodiments without departing from the generic concept, and, therefore, such adaptations and modifications should and are intended to be comprehended within the meaning and range of equivalents of the disclosed embodiments. It is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation. Therefore, while the embodiments herein have been described in terms of preferred embodiments, those skilled in the art will recognize that the embodiments herein can be practiced with modification within the spirit and scope of the appended claims.

[0098] Although the embodiments herein are described with various specific embodiments, it will be obvious for a person skilled in the art to practice the embodiments herein with modifications. However, all such modifications are deemed to be within the scope of the claims.

[0099] It is also to be understood that the following claims are intended to cover all of the generic and specific features of the embodiments described herein and all the statements of the scope of the embodiments, which as a matter of language might be said to fall there between.

What is claimed is:

1. An internal refrigeration method for separating a residue gas from an input gas to recover a natural liquid gas through a self-refrigeration process comprising steps of:
   - feeding an input gas into an internal refrigeration system;
   - condensing the input gas in a first multi-flow heat exchanger;
   - separating an output of the first multi-flow heat exchanger into a fluid stream and a gas stream using a first drum separator;
   - dividing the separated gas stream obtained from the first drum separator into a first gas part and a second gas part;
   - dividing the separated fluid stream obtained from the first drum separator into a first fluid part and a second fluid part;
   - passing the first fluid part obtained from the first drum separator to a middle section of a demethanizer column through a Joule-Thomson expansion valve for further fractionating;
   - passing the second fluid part obtained from the first drum separator to a top rectifying section in the demethanizer column through a second multi-flow heat exchanger and a first expansion valve to form a residue gas;
   - passing the first gas part to a work expander device;
passing a gas stream output of the work expander device to an area below a top rectifying section in the demethanizer column as an expander discharge; 
passing the second gas part through the second multi-flow heat exchanger and a second expansion valve to the top rectifying section in the demethanizer column to form a reflux liquid; 
passing the residue gas from the top rectifying section of the demethanizer column through the second multi-flow heat exchanger and the first multi-flow heat exchanger to a first compressor for further compression, and wherein the first compressor compresses the residue gas using a work extracted from the expander device; 
passing a compressed residue gas output from the first compressor to a second compressor for further compressing the residue gas; 
passing the further compressed residue gas through a first air cooler; 
forwarding an output of the first cooler as a gas refrigerant; 
stripping off volatile components from a liquid collected at a bottom portion of the demethanizer column by circulating liquids from four liquid draw trays provided in the bottom portion of the demethanizer column through the first multi-flow heat exchanger and the second multi-flow heat exchanger and collecting back the liquids at the demethanizer column; and 
recovering the liquids from a bottom portion of the demethanizer column.

2. The method according to claim 1, wherein a step of stripping off volatile components from the liquid collected at the bottom portion of the demethanizer column comprises:

drawing a liquid from a first liquid tray and passing through the second multi-flow heat exchanger before being collected back at the demethanizer;

drawing a liquid from a second liquid tray and passing through the second multi-flow heat exchanger before being collected back at the demethanizer, wherein a direction of flow of the liquid from the first liquid tray through the second multi-flow heat exchanger and a direction of flow of the liquid from the second liquid tray through the second multi-flow heat exchanger are mutually opposite;

drawing a liquid from a third liquid tray and passing through the first multi-flow heat exchanger before being collected back at the demethanizer;

drawing a liquid from a fourth liquid tray and passing through the first multi-flow heat exchanger before being collected back at the demethanizer, wherein a direction of flow of the liquid from the third liquid tray through the first multi-flow heat exchanger and a direction of flow of the liquid from the fourth liquid tray through the first multi-flow heat exchanger are mutually opposite.

3. The method according to claim 2, wherein step of drawing liquid from the fourth liquid tray and passing through the multi-flow heat exchanger before being collected at the demethanizer column comprises:

passing a liquid drawn from the fourth tray through the first multi-flow heat exchanger;

passing an output of the first multi-flow heat exchanger to a second drum separator through a third expansion valve;

feeding a vapor output from the second drum to a first stage of a third compressor;

passing an output of the third compressor to a second air cooler through a third multi-flow heat exchanger;

forwarding an output of the second air cooler to a third drum separator for dividing the output of the second air cooler into a vapor part and a liquid part;

dividing the liquid part obtained from the second air cooler into a third liquid part and a fourth liquid part;

combining the vapor part and the third liquid part obtained from the third drum separator;

forwarding the combined the vapor part and the third liquid part obtained from the third drum separator to the demethanizer;

passing the fourth liquid part obtained from the third drum separator to the third multi-flow heat exchanger through a fourth expansion valve;

dividing an output of the third multi-flow heat exchanger into a fifth liquid part and a sixth liquid part;

passing the fifth liquid part from the output of the third multi-flow heat exchanger to the second drum separator;

feeding the sixth liquid part from the output of the third multi-flow heat exchanger to a fourth drum separator to obtain a vaporized liquid and a non-vaporized liquid;

forwarding the vaporized liquid obtained from the fourth drum separator to a second stage of the third compressor;

combining and forwarding the non-vaporized liquid from the fourth drum separator and the non-vaporized liquid from the second drum separator to the demethanizer.

4. The method according to claim 1, wherein the input gas is a light gas containing a low amount of hydrocarbons that are converted into a natural gas liquid.

5. The method according to claim 1, wherein the natural gas liquid has a lower volatility degree as compared to that of the residue gas.

6. A method of external refrigeration for separating a residue gas from an input gas to recover a natural liquid gas through a propane-refrigeration process comprising steps of:

feeding an input gas into an internal refrigeration system;

condensing the input gas in a first multi-flow heat exchanger;

separating an output of the first multi-flow heat exchanger into a fluid stream and a gas stream using a first drum separator;

dividing the separated gas stream obtained from the first drum separator into a first gas part and a second gas part;

dividing the separated fluid stream obtained from the first drum separator into a first fluid part and a second fluid part;

passing the first fluid part obtained from the first drum separator to a middle section of a demethanizer column through a Joule-Thomson expansion valve for further fractionating;

passing the second fluid part obtained from the first drum separator to a top rectifying section in the demethanizer column through a second multi-flow heat exchanger and a first expansion valve to form a residue gas;

passing the first gas part to a work expander device;

passing a gas stream output of the work expander device to an area below a top rectifying section in the demethanizer column as an expander discharge;

passing the second gas part through the second multi-flow heat exchanger and a second expansion valve to the top rectifying section in the demethanizer column to form a reflux liquid;
passing the residue gas from the top rectifying section of the demethanizer column through the second multi-flow heat exchanger and the first multi-flow heat exchanger to a first compressor for further compression, and wherein the first compressor compresses the residue gas using a work extracted from the expander device;
passing a compressed residue gas output from the first compressor to a second compressor for further compressing the residue gas;
passing the further compressed residue gas through a first air cooler;
forwarding an output of the first cooler as a gas refrigerant;
stripping off volatile components from a liquid collected at a bottom portion of the demethanizer column by circulating liquids from four liquid draw trays provided in the bottom portion of the demethanizer column through the first multi-flow heat exchanger and the second multi-flow heat exchanger and collecting back the liquids at the demethanizer column;
recovering the liquids from a bottom portion of the demethanizer column; and providing an external refrigeration process using liquid propane.

7. The method according to claim 6, wherein a step of stripping off volatile components from the liquid collected at the bottom portion of the demethanizer column comprises:
drawing a liquid from a first liquid tray and passing through the second multi-flow heat exchanger before being collected back at the demethanizer;
drawing a liquid from a second liquid tray and passing through the second multi-flow heat exchanger before being collected back at the demethanizer, wherein a direction of flow of the liquid from the first liquid tray through the second multi-flow heat exchanger and a direction of flow of the liquid from the second liquid tray through the second multi-flow heat exchanger are mutually opposite;
drawing a liquid from a third liquid tray and passing through the first multi-flow heat exchanger before being collected back at the demethanizer;
drawing a liquid from a fourth liquid tray and passing through the first multi-flow heat exchanger before being collected back at the demethanizer, wherein a direction of flow of the liquid from the third liquid tray through the first multi-flow heat exchanger and a direction of flow of the liquid from the fourth liquid tray through the first multi-flow heat exchanger are mutually opposite.

8. The method according to claim 6, wherein a step of providing external refrigeration using propane comprising steps of:
feeding a compressed liquid propane from a third compressor into a second air cooler;
forwarding an output of the second air cooler to a second drum separator through a third expansion valve;
passing a liquid propane output from the second drum separator through a fourth expansion valve;
forwarding a vapor gas output of liquid propane from the second drum separator to the stage of a third compressor passing an output liquid propane passed from the second drum separator through the fourth expansion valve;
dividing an output liquid propane passed through the fourth expansion valve into a first liquid propane part and a liquid propane part;
feeding the first liquid propane part output from the fourth expansion valve to a first multi-flow heat exchanger for providing a required refrigeration for cooling the feed gas;
forwarding the first liquid propane part output from the first multi-flow heat exchanger to a third drum separator;
feeding the second liquid propane part output from the fourth expansion valve to the third drum separator directly through a sixth expansion valve;
forwarding a vapor gas output of the third drum separator to a second stage of the third compressor;
feeding a non-vaporized liquid output from the third drum separator to a fourth drum separator after passing the non-vaporized liquid output from the third drum separator through a seventh expansion valve, the second multi-flow heat exchanger and the first multi-flow heat exchanger;
passing a vaporized output from the fourth drum separator to a first stage of the third compressor; and forwarding a liquid propane output from the fourth drum separator as an external refrigerant.

9. A system for separating a residue gas from an input gas to recover a natural liquid gas comprising:
a self-refrigeration unit comprising an open-closed cycle of refrigeration; and an external refrigeration unit;
wherein the self-refrigeration unit comprising an open-closed cycle of refrigeration provides a required refrigeration load and wherein the external refrigeration unit provides a refrigeration load corresponding to variations in a feed composition percentage.

* * * * *