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Lofredo et al.

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[54] **LIQUEFACTION OF NATURAL GAS WITH PRODUCT USED AS ABSORBER PURGE**

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[58] **Field of Search** 62/9, 11, 17, 18, 62/23, 24, 26, 27, 28, 30, 39, 40, 50, 54; 55/62, 73, 74, 80

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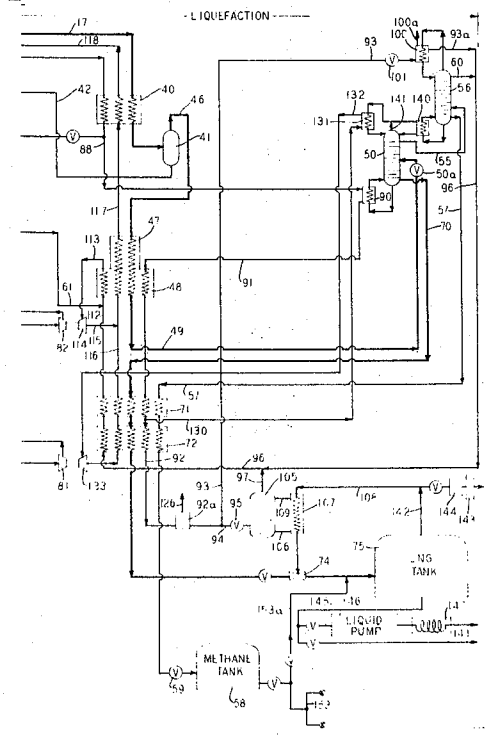
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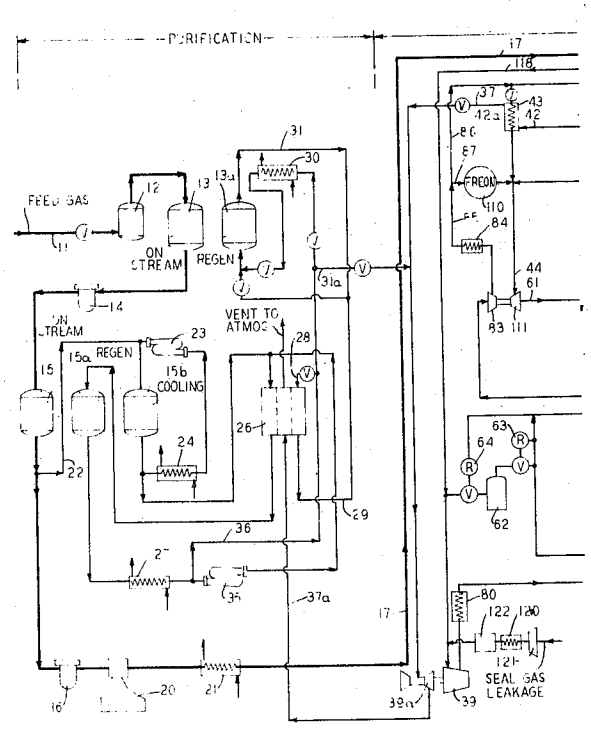
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[57] **ABSTRACT**

This invention relates to a process for purifying and liquefying a natural gas stream comprising the steps of passing said stream through absorption units to remove impurities, compressing said stream, liquefying said stream by heat exchange with a low temperature nitrogen refrigeration cycle, stripping the nitrogen from said liquefied stream, utilizing said nitrogen in said refrigeration cycle, storing a portion of said liquefied stream, and condensing the boil-off from said storage with low temperature nitrogen from said cycle.

13 Claims, 2 Drawing Figures





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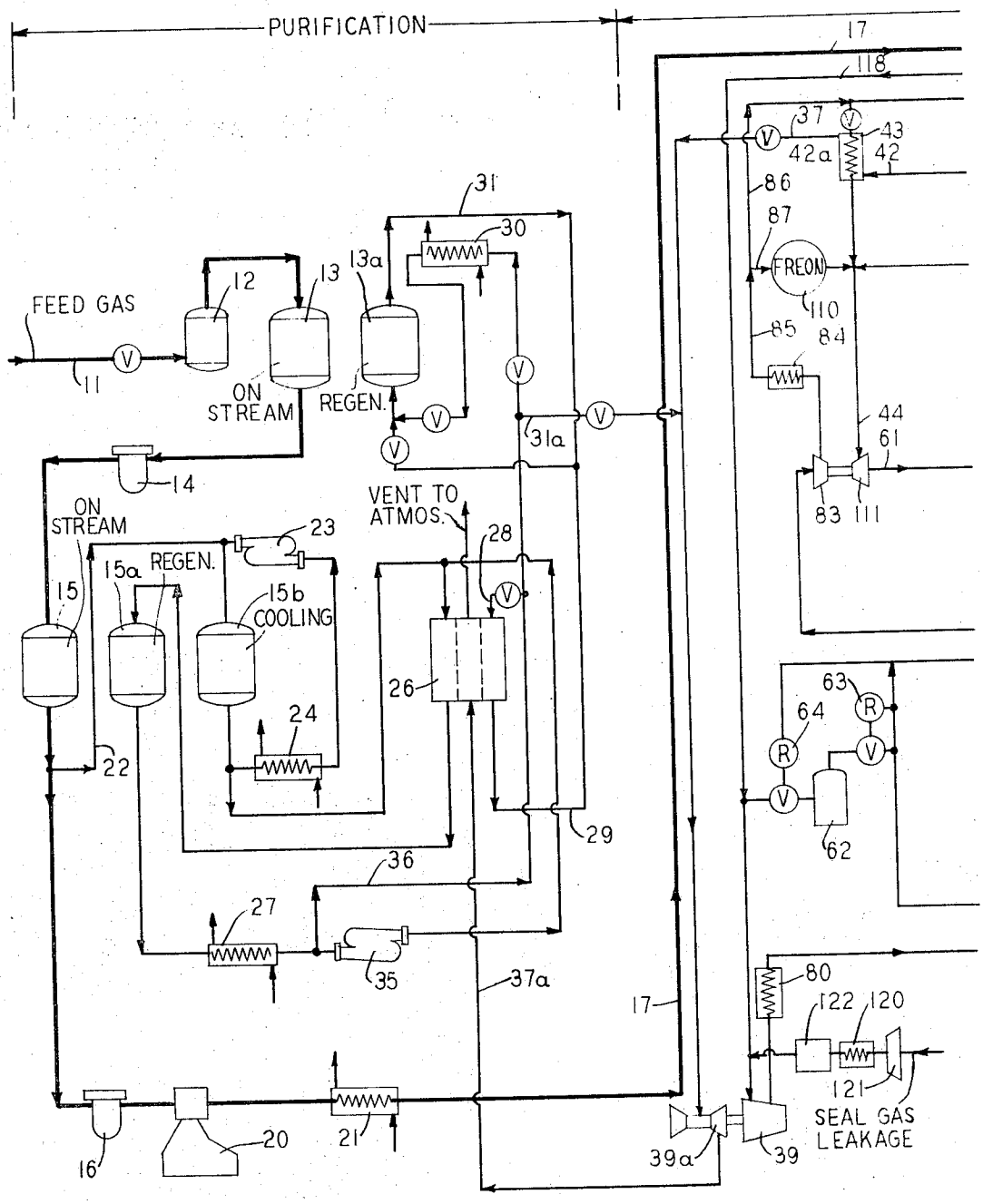


FIG. 1

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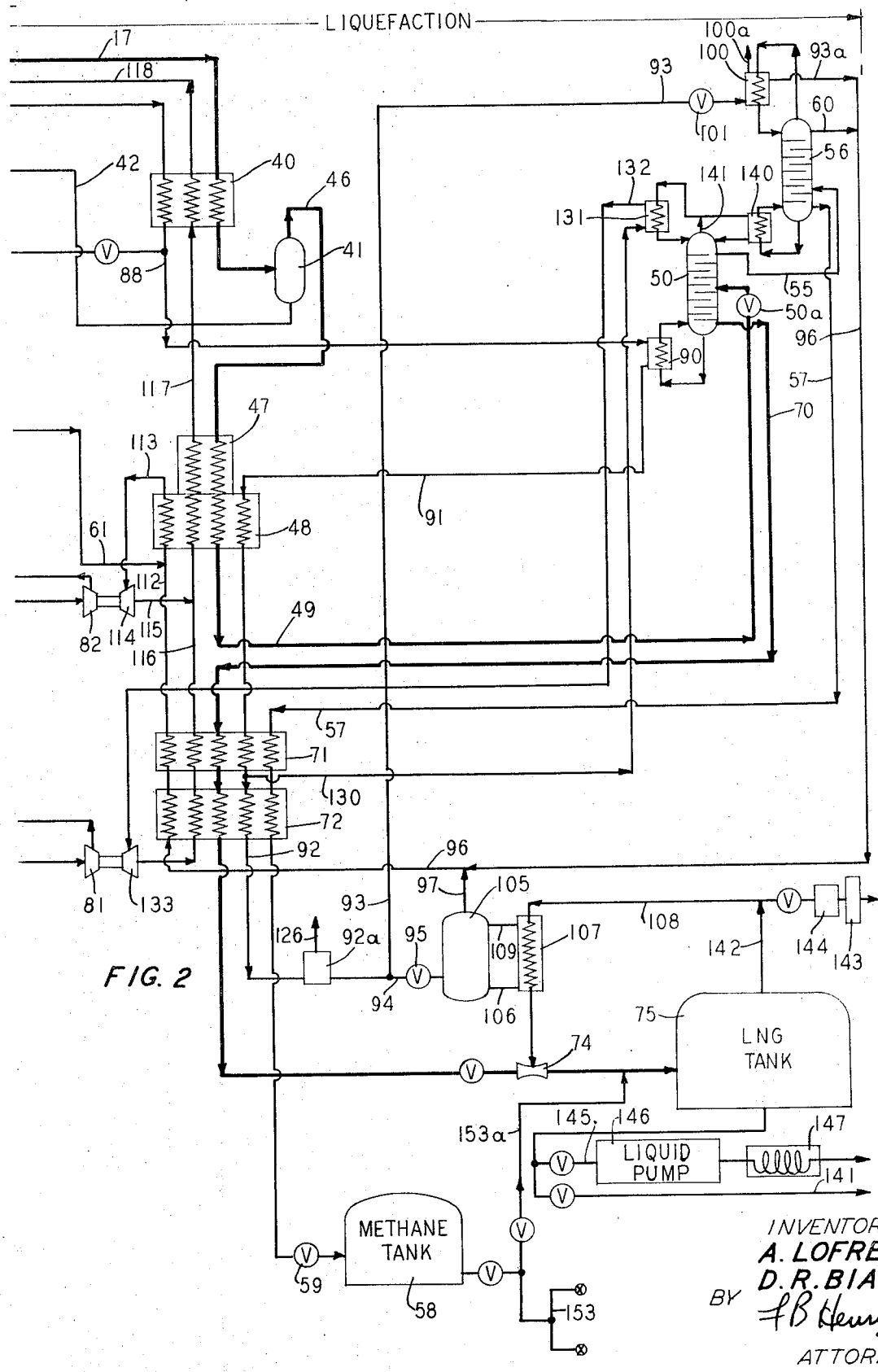


FIG. 2

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LIQUEFACTION OF NATURAL GAS WITH PRODUCT USED AS ABSORBER PURGE

In recent years the usage of natural gas as a fuel in both commercial and household applications has increased tremendously and a network of natural gas pipelines has developed throughout the country. Due to the fact that the supply of natural gas into the distribution network is relatively constant the gas distribution system is inherently unable to deliver to users more gas than is supplied to the distribution system. In order to anticipate seasonal loads (winter months), unexpected loads, and to insure continuity of service it has been found necessary to store the natural gas at various locations throughout the country. One method of doing this is of course to store natural gas in its gaseous form in containers or tanks which are capable of satisfying peak loads. This method of storage is not, however, attractive due to the fact that large tanks which are capable of storing gas at high pressures are both expensive and unsightly.

The utilities and other companies which use natural gas have therefore begun to store the natural gas in liquid form. In recent years a number of natural gas liquefaction plants have been developed throughout the world. The majority of these plants liquefy the natural gas which comes from a gas distribution system and store the resulting liquid in large insulated vessels. When a peak demand occurs, the liquid storage is drawn down and vaporized and supplied to the user to supplement the gas which is normally supplied from the gas distribution system. LNG plants have also been installed at points of shipment (i.e., seaports, etc.) since the gas is usually shipped in liquid form.

The liquefaction cycles which were employed in the prior art plants have important disadvantages and limitations. Most of the prior art cycles employ cascade or modified cascade refrigeration cycles. These cycles are extremely complicated in view of the fact that a plurality of refrigerants are used and these require separate sources of supply and different expansion and compression equipment. The prior art systems furthermore generally utilize expensive compressors and heat exchangers, etc. A plant built according to the present invention utilizes centrifugal machinery at high efficiencies and eliminates the need for cold blowers and cold pumps for the transfer of LNG to storage. The subject design also provides for the control of composition of the LNG in storage and eliminates the high boilers in storage. In addition natural gas is used in an efficient manner to regenerate the absorbers and then to drive compressors.

It is the principal object of the present invention to utilize a non-hydrocarbon gas in the refrigerant cycle for liquefying natural gas. Since the refrigerant is a non-hydrocarbon and its properties are well known and well defined, its thermodynamic and physical properties in the refrigeration cycle can be accurately predicted.

It is a further object of the present invention to utilize natural gas to regenerate absorbers in an economical fashion. It is a further object of the present invention to utilize natural gas as a fuel to drive the gas turbine which drives the main compressor for the refrigeration cycle.

It is another object of the present invention to utilize a refrigerant fluid which can be obtained from the natural gas which is being liquefied. This will allow the refrigeration cycle to be self sufficient so that deliveries

of refrigerant fluid from outside the area of the liquefaction plant will not be necessary.

It is another object of the present invention to liquefy at least part of the refrigerant fluid and to then use the refrigerant liquid to maintain a constant LNG composition in the storage tank by liquefying the apors which are generated in the storage tank.

It is another object of the present invention to purify the input natural gas and to obtain therefrom essentially pure methane.

These and other objects of the present invention will become apparent from the following description and the accompanying drawing in which:

FIGS. 1 and 2 when taken together show a flow diagram of a liquefied natural gas plant according to one embodiment of the present invention.

Referring to FIG. 1, natural gas enters the process through conduit 11. The feed gas generally comes from a distribution network or it may come directly from a natural gas well head or other source. The inlet temperature, pressure and flow of the feed gas remain relatively constant and the particular system is designed accordingly. In a typical instance the infeed gas is at approximately 200 psig and 85°F and flows at the rate of about 10 MM SCFD. The system would of course be readily adapted to accommodate other inlet pressures, temperatures and flows.

A typical natural gas feed stream contains methane, nitrogen, ethane and other hydrocarbons down to pentanes in varying proportions. The particular embodiment of the invention which will now be described for purposes of illustration is especially suited for treating and liquefying natural gas having the following major constituents in mol percents: N_2 – 3 percent, methane – 88 percent, ethane – 6 percent, propane – 1 percent, CO_2, 1 percent and remaining impurities.

The feed stream passes through separator 12 which removes the entrained liquid odorants, sulphurs, etc. The feed gas is then dried to approximately −100°F dew point in the desiccant drier (molecular sieve) drier 13. This drier is one of a pair of adsorption driers, 13, 13A, which serves to further remove moisture and odorants, sulphurs and sulphur compounds from the feed gas stream. As shown in FIG. 1 adsorber 13 is on stream while adsorber 13A is being regenerated. The regeneration process will be described in detail hereinbelow. The feed stream then proceeds through a filter 14 which removes any adsorber particles which may have been entrained in the gas stream as it passes through the adsorber 13. Carbon dioxide and remaining odorant, sulphur and sulphur compounds are removed in adsorption unit 15. As shown in FIG. 1, unit 15 is on stream while unit 15A is being regenerated and while unit 15B is being cooled. The adsorption units 15 may take the form of ambient temperature molecular sieve adsorption units. The main purpose of these units is to remove the CO_2 and the abovementioned contaminants from the feed gas stream.

After the feed gas passes through adsorber 15 it proceeds through a further adsorber particle filter 16. The feed gas is then compressed to an optimum pressure of between 600–700 psia by feed gas compressor 20. The necessity for this compressor of course depends upon the pressure of the feed gas entering the system. After being compressed in compressor 20 the feed gas passes through an after cooler 21 wherein it is cooled with water in the conventional manner. The compressed and

cooled feed gas then enters the liquefaction portion of the process.

Before proceeding with the description of the liquefaction cycle, a more detailed description of the abovedescribed purification equipment will now be given in view of the fact that this forms an important portion of the present invention.

A portion (approximately 14 percent) of the incoming feed gas is diverted through conduit **22** to a cooling cycle for adsorber **15***b*. This cycle includes a cool-down blower **23** which pulls a suction on a cool-down exchanger **24** which is water cooled. The cool-down blower **23** circulates cool natural gas through the adsorber **15***b* to cool the molecular sieve adsorption unit after regeneration to a desirable temperature. While this cooling is taking place adsorber **15***a* is being regenerated with hot natural gas which comes from regeneration heater **26.** The heater **26** is warmed up by using the waste heat from the gas turbine which drives the compressor **39.** The natural gas coming from the adsorber **15***a* passes through a cooler **27** wherein it is cooled with water in an indirect manner and a portion of this cooled natural gas is then utilized to regenerate the adsorption unit **13***a*. The regeneration of adsorber unit **13***a* occurs by first heating the unit to drive off the accumulated water and by then cooling the unit to the desired temperature. During the time when the unit is being heated the regeneration gas is heated in heater **26** by passing it through conduits **28** and **29** and then upwardly through unit **13***a*. When sufficient heating of the unit has taken place the unit is cooled by directing the regenerative gas through cooling unit **30** which is cooled by water and the flow through conduits **28** and **29** is stopped by a suitable valve arrangement. The cooled natural gas after flowing through heat exchanger **30** then passes up through adsorption unit **13***a* to cool the same to the desired temperature. The natural gas which leaves the unit **13***a* passes through suitable conduit **31,** joins with the flow from conduit **31***a*, and then passes to the gas turbine **39***a* wherein it is used as the fuel which drives the turbine. It is not necessary that all of the gas flowing through conduit **36** pass through the adsorber being regenerated or cooled and therefore a portion of the flow is bypassed through conduit **31***a*. A flow regulating valve is placed in conduit **31***a* to control the flow. Although a turbine is preferred as the driving force for the compressor **39,** any suitable engine may be used. Hereinafter the term "engine" is used in a generic sense to describe turbines, reciprocating engines, etc. As mentioned above, the exhaust gases from this engine or turbine are used in the regenerative heater **26.**

A portion of the cooled natural gas stream coming from cooling unit **27** is drawn into regeneration blower **35** which forces this portion through the regenerative heater **26** and then into the adsorption unit which is being regenerated **15***a*.

The unique flow arrangement of this semi-open system requires the use of only a minimum amount of regeneration gas, because of the recirculation feature. A regeneration flow is circulated by blower **35,** heated to approximately 550°F by the gas turbine exhaust gas in heat exchanger unit **26,** and then passes through the molecular sieve absorption unit being regenerated and in the case of FIG. **1** this would be unit **15***a*. The gas is then cooled in cooling unit **27** to an allowable blower inlet temperature and recirculated by means of the blower **35.** Note that a similar loop is provided utilizing blower **23** and heat exchanger **24** for cooling the molecular sieve adsorption unit after it has been regenerated. The three molecular sieve adsorption units are arranged so that at a given period of time, one unit will be in active service, one will be in regeneration and the third will be in cool-down. The flows for the three operations are sequenced by an automatic timer controlling pneumatic valves in a manifolded system. In a typical operation a 2 hour cycle is utilized. This depends on CO_2 content and the equipment used. After adsorption unit **15** has been on-stream for 2 hours, the timing device will be actuated and direct the feed gas flow to unit **15***b* which has just undergone cooling. The regeneration stream will be directed to unit **15** to regenerate the same and the cooling stream will be directed to unit **15***a* to cool the same. When unit **15***b* has been on stream for a 2 hour cycle, the feed gas will be directed to unit **15***a*, etc. The details of the automatic timer controlling circuit with its associated valves is not described in detail in this application in view of the fact that this type of control apparatus is well known in the art and may take many forms. For example the valves may be either pneumatically, electrically or hydraulically operated.

The regeneration and cooling recycle streams are continuously purged with a bleed stream (**22**) of purified, dry natural gas to prevent an excessive buildup of contaminants in the streams. As shown the bleed stream flow enters the cool-down reycle stream and is in turn vented into the regeneration recycle stream.

The bleed stream is removed through conduit **36** from the regeneration cycle stream at the suction side of blower **35.** The bleed stream is then alternately heated by gas turbine exhaust gas in exchanger **26** or cooled in exchanger **30,** respectively, to regenerate and cool the adsorption driers **13, 13***a*.

The adsorption driers **13, 13***a* are arranged and controlled similarly to the molecular sieve adsorption units **15, 15***a*, **15***b*. During the regeneration cycle each adsorption drier is first heated by the purge gas which has passed through the heater **26** and is then cooled by the purged gas which has passed through the cooling unit **30.** A suitable timing device coupled with responsive control valves control the flow of the purge gas through the adsorption drier being regenerated. After an adsorption drier has been on stream for a predetermined period of time, for example 8 hours, a timing circuit will direct the incoming feed gas to the adsorption drier which has just undergone regeneration and will place the drier which has been on stream in the abovedescribed regeneration cycle. Cycle time depends on water content and equipment.

After the bleed or purge stream has passed through the adsorption drier undergoing regeneration it is subsequently vented into the fuel gas system for the gas turbine driver through conduit **31.** This fuel stream joins with stream **31***a* and with fuel stream **37** and goes to the gas turbine **39***a*. The hot exhaust from the turbine flows through a suitable conduit **37***a* and flows through heat exchanger **26** to warm the same. Thus our invention provides a unique process for efficiently regenerating the adsorption units and for providing fuel gas to the refrigeration compressor.

The compressed and cooled main feed stream enters the liquefier portion of the process through conduit **17,** the main flow stream being indicated in heavier lines in

FIG. 1. The natural gas which is delivered to the liquefier portion is essentially dry, purified, and of a suitable pressure. A suitable pressure for the instant embodiment was found to be approximately 650 psia at ambient temperature. This stream is cooled by nitrogen in exchanger **40.** The temperature of the natural gas stream is lowered in this exchanger to approximately −75°F. At this temperature and pressure approximately 1 percent of the feed gas will separate as liquid in the separator **41.** Substantially all heavy hydrocarbons (C_5+) will be removed in the separator **41** and will be found in the liquid phase. The liquid formed in the separator passes through conduit **42** into exchanger **43** wherein its refrigeration capacity is given up to the refrigerant stream. An expansion valve **42a** is provided in line **37** to reduce the pressure of the stream to the fuel gas system pressure. After the liquid has been boiled off in exchanger **43** it proceeds through conduit **37** to the fuel gas supply system to the engine **39***a*. The amount of refrigerant nitrogen passing through exchanger **43** is regulated so that all the available refrigeration of liquid stream **37** is recovered.

The vapor from separator **41,** which is approximately 90 percent methane, passes through conduit **46** into balancing exchanger **47** and then into liquefier **48** wherein the stream is liquefied. The liquefied stream passes through conduit **49** into a nitrogen stripping column **50** which is operated at approximately 600 psia. The stream **49** is expanded by means of a suitable pressure controller **50***a* to the desired column pressure.

Methane, free of heavy hydrocarbons, but including all the nitrogen in the feed gas, is taken off the top of the stripping column through conduit **55** and fed into the nitrogen-methane column **56.** In the nitrogen-methane column essentially pure methane is made and nitrogen which can be used in the refrigeration cycle is also separated out. The details of this column will be described below. Liquefied natural gas from the bottom of the nitrogen stripping column **50** passes through conduit **70** through exchangers **71** and **72** wherein the natural gas is subcooled. The subcooled stream passes through eductor **74** and then into the LNG storage tank **75** with essentially no flash.

As mentioned above, same methane which includes all of the nitrogen in the feed gas is taken off of the nitrogen stripping column **50** and is fed through conduit **55** into nitrogen methane column **56.** Essentially pure (99+percent) methane is removed from the lower portion of this column and passed through conduit **57** into exchangers **71** and **72** wherein it is subcooled and it then passes through an expansion device **59** without flash into a methane tank **58** wherein it is stored in liquid form at a pressure above ambient. The methane that is stored can be used to "sweeten" the LNG in the main tank or distributed elsewhere as a pure product through piping system **153.** Methane is transferred to the main tank or loading station by storage pressure differential through line **153***a*.

The nitrogen is removed from the top of the column **56** through conduit **60** and passed through exchangers **72** and **71** to remove the refrigeration therefrom and this stream then couples with the nitrogen refrigeration stream **61.** An automatic vent arrangement **100***a* is provided on condenser **100** to vent helium and other low boilers that may be present in the feed gas. The combined stream enters liquefier **48.** Thus the nitrogen which is in the natural gas feed stream is removed therefrom in the instant purification-liquefaction process and is utilized in the refrigeration cycle. Since the amount of nitrogen returned to the suction of the nitrogen compressor is greater than the high pressure nitrogen flow to the liquefier by the amount of nitrogen stripped from the natural gas, an inventory or nitrogen is accumulated in the storage tank **62,** which also serves as a surge tank. When a surplus of nitrogen is available, the high pressure nitrogen head pressure increases and the surplus nitrogen is put into storage tank **62** by pressure control valve **63.** When additional nitrogen is required by the cycle, the high pressure nitrogen head pressure decreases and the additional nitrogen is taken from the storage tank **62** by pressure controller **64** and flows into the cycle nitrogen compressor suction.

A description of the refrigeration cycle which may be described as a closed loop nitrogen cycle providing all the refrigeration required to liquefy the natural feed gas will now be given.

Nitrogen is compressed to approximately 400 psia in cycle nitrogen compressor **39** and is then after-cooled in after-cooler **80.** This pressure is optimum for the conditions of the present cycle but could be varied to suit other conditions. The nitrogen is then further compressed in compressors **81, 82** and **83** to approximately 650 psia. After leaving compressor **83** the nitrogen is sent through a conventional after cooler **84** to remove the heat of compression. The nitrogen then proceeds through conduit **85** and is split into two streams **86** and **87.** Most (75 percent) of the high pressure feed proceeds through conduit **86** into heat exchanger **40** wherein it is cooled. The cooled stream **88** which leaves the exchanger **40** then proceeds to reboiler **90** wherein it is further cooled by boiling the liquid obtained from the lowest portion of the nitrogen stripping column. The cooled nitrogen stream is further cooled as it proceeds through conduit **91** and passes through liquefier **48** and subcooling heat exchangers **71** and **72.** The nitrogen is substantially liquefied in exchanger **72** and then passes through conduit **92** into a chamber **92a** with an automatic vent **926** to purge the system of non-condensible helium and other low boilers. It is then split into two streams, one of which proceeds through conduit **93** and the other which proceeds through conduit **94** to expansion valve **95.** The nitrogen liquid which proceeds through conduit **93** is used in condenser **100** after it is expanded through valve **101** to a suitable pressure (approximately 160 psia). The liquid serves to condense the nitrogen obtained from the top of the methane column to produce reflux for the column. The nitrogen which is boiled off combines **93***a* with the nitrogen and low boilers which are leaving the column through conduit **60** and they then flow via conduit **96** to the exchangers. The portion of the liquid which proceeds through conduit **94** is expanded through valve **95** into liquid nitrogen separator **105.** The pressure in the separator is dependent upon the selected operating pressure of the cycle compressor **39.** The liquid nitrogen passes through conduit **106** into boil-off condenser **107** wherein the liquid nitrogen is itself boiled off and returns via conduit **109,** while condensing the boil-off from LNG tank **75.** The nitrogen which is thus boiled off escapes through conduit **97** and joins with the stream **96.** The natural gas boil-off is drawn through conduit **108** into the boil-off condenser **107** by means of the thermosiphon action of the cold condenser. The condenser boil-off is returned to the

LNG tank by means of eductor **74.** By condensing the boil-off and returning it to the LNG tank the composition of the liquid natural gas which is stored in the tank in liquid form is maintained constant. If no provision were made for recondensing the boil-off the composition of the liquid remaining in the tank would change over a period of time due to the fact that the high boilers would boil off first leaving the lower boilers in liquid form.

The portion (24 percent) of the nitrogen refrigerant which passes through conduit **87** is cooled in a freon refrigeration unit **110** to approximately −20°F. Other types of refrigeration systems could be used in place of a freon system and it has been found that under certain circumstances there is no need for additional refrigeration at this point. This stream is then joined with the portion of the nitrogen stream which has been allowed to come through exchanger **43.** The combined stream then passes through conduit **44** to high level expander **111** wherein the nitrogen is expanded to a lower pressure and temperature (160 psi, −145°F) and passed through liquefier **48** in countercurrent relationship with the product stream which is being cooled. Note that the stream **61** combines with stream **112** which is made up of the boil-off from the liquid nitrogen separator **105,** the boil-off from the condenser **100** and the nitrogen and low boilers obtained via conduit **60** from the upper portion of the methane column **56.** These combined streams serve to assist in cooling and liquefying the natural gas passing through liquefier **48.** The combined and warmed streams then pass through conduit **113** into reheat expander **114** wherein the gases are expanded to a lower temperature (−150°F) and pressure (85 psia). The gases then pass through conduit **115** and combine with gases from conduit **116** and flow through liquefier **48,** heat exchanger **47,** and then through conduit **117** into heat exchanger **40** and then return through conduit **118** to the suction side of the compressor **39.**

Shaft seal leakage from cycle compressor **39** and the expander/compressors is trapped out of the oil systems of these units, recompressed by a seal gas compressor **121,** cooled in after-cooler **120** and delivered to the suction side of the compressor **39.** Oil vapor is removed in a suitable adsorption filter **122.** Thus the seal gas leakage is returned to the cycle nitrogen compressor section for reuse.

During periods when the liquefier is inoperative, the nitrogen refrigerant gas is stored at ambient conditions in storage tank **62** which was described above and which can be sealed off. The storage tank **62** is sized to accommodate a full refrigerant gas charge, thus allowing stop-restart operations typical of peak shaving plants with no refrigerant inventory problems.

The majority (90 percent) of the main refrigerant gas stream which passes into liquefier **48** from conduit **91** is split from the main stream after it has passed through heat exchanger **71.** This is directed through conduit **130** and proceeds to nitrogen stripping column condenser **131** wherein it serves to condense the vapor coming from the top of the nitrogen stripping column to provide reflux therefor. The nitrogen vapor coming from the condenser **131** passes through conduit **132** and is expanded in low level expander **133** to a lower temperature (−265°F) and pressure (90 psia) and then it is passed through heat exchanger **72** and **71** and into conduit **116** which then joins the stream in conduit **115** for passing through the liquefier **48.**

Part of the reflux for the nitrogen stripping column comes from nitrogen methane rectification column reboiler **140.** This reboiler boils the liquid which is obtained from the lower portion of the column **56** and at the same time condenses a portion of the vapor which passes from the top of column **50** through conduit **141.** Note that the vapor coming from conduit **141** is split to pass through both the condenser **131** and the reboiler **140.** This has been found to be a most economical way to produce reflux for the column **50** and to boil off the liquid collected in the bottom of the column **56.**

It is readily apparent that the process described in detail above is especially suited not only for situations wherein the total amount of feed gas introduced is liquefied and stored for use at a future date, but also for situations wherein only a selected portion of the feed gas is liquefied. The LNG which is stored in the storage tank **75** may be withdrawn in liquid form. To ship liquefied natural gas by truck, etc., to remote locations it is only necessary that the liquid be withdrawn through conduit **141** and transferred into the transport vehicle. In a typical system the head of liquid in the tank will serve to transfer the liquid into a transport vehicle. During times when the liquefier is not in operation, the vapor which is in the tank above the liquid is withdrawn through conduit **142.** To bring the gas up to proper pressure for entrance into the distribution network, it is passed through a heater **144** and then the distribution network, it is passed through a heater **144** and then compressed by suitable compressor **143** and then forwarded to the distribution network. For peak showing requirements, liquid may be withdrawn through conduit **145** and pumped in a suitable liquid pump **146** and then forwarded to a vaporizing unit **147.** The vaporized product may be then forwarded to the distribution network as desired. The details regarding the construction of the LNG tank **75** are not described in detail due to the fact that this may be a conventional tank design to store cryogenic fluids. The tank is normally operated at 0 psig. The methane tank **58** stores essentially pure liquid methane which may be used to sweeten the product in the LNG tank if this is found necessary.

The operation of the liquefier and distribution columns and associated equipment can be controlled to vary the methane concentration of the LNG sent to storage tank **75** which provides the advantage of producing LNG within acceptable calorific limits.

Whereas this invention has been described primarily with respect to the liquefaction of natural gas and is especially suited therefor, it may also be used for the liquefaction of other gases. The temperatures, pressures, flow rates, etc., have been cited for purposes of illustration and to facilitate an understanding of the invention. These may be varied to satisfy required conditions.

The preferred embodiment of the present invention has been described in detail, however it is apparent that modifications to the process and apparatus may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. A process for the production of substantially pure methane and liquefied natural gas from a feed stream of natural gas comprising the steps of:

a. purifying said feed streams to remove moisture and carbon dioxide, said purification step being at least

partially accomplished by passing the said natural gas stream through adsorption units, regenerating said units using a recirculating stream of warm natural gas, and cooling said units following regeneration with a recirculating stream of cool natural gas, while continuously purging said warm and cool streams by providing to said streams a bleed stream of purified, dry, natural gas taken from said feed stream beyond said adsorber units, to prevent an excessive buildup of contaminants;

b. removing heavy hydrocarbons from said feed stream;

c. liquefying said feed stream by heat exchange with a closed loop nitrogen refrigeration cycle;

d. rectifying said liquefied feed stream to strip nitrogen and part of the methane therefrom;

e. separately, further rectifying said stripped nitrogen and methane to produce substantially pure methane;

f. supplying said further rectified nitrogen to the refrigeration cycle to replace the losses, and accumulating an inventory of excess nitrogen for use in replenishing said losses in said cycle, and directing the substantially pure methane to a storage facility; and

g. subcooling the remaining liquefied natural gas feed stream and directing the same to a storage facility.

2. A process according to claim **1,** wherein step (b) is accomplished by liquefying said heavy hydrocarbons and separating said liquefied hydrocarbons from said stream.

3. A process according to claim **2,** further comprising cooling at least a portion of the high pressure nitrogen feed stream in said refrigeration cycle with said hydrocarbons.

4. A process according to claim **2,** wherein said hydrocarbons are used as fuel to drive a compressor in said refrigeration cycle.

5. A process according to claim **1,** including venting said bleed stream following purging into a fuel gas stream for driving a compressor in said refrigeration cycle.

6. A process according to claim **1** including withdrawing the boil-off from the LNG storage facility and condensing the same by heat exchange with liquid nitrogen from the refrigeration cycle, returning the condensed boil-off to the storage facility.

7. A process according to claim **6** wherein the condensed boil-off is joined by means of an eductor with the liquefied natural gas being directed to the storage facility.

8. A process according to claim **1** including sweetening the liquefied natural gas in the storage facility by introducing substantially pure methane into said facility.

9. A process for the production of substantially pure methane and liquefied natural gas from a feed stream of natural gas comprising the steps of:

a. removing moisture and carbon dioxide from said feed stream;

b. liquefying at least part of the hydrocarbons heavier than methane in a first cooling step;

c. separating said at least part from said feed stream;

d. liquefying said feed stream in a second cooling step;

e. rectifying said liquefied feed stream to strip nitrogen and at least part of the methane therefrom;

f. further rectifying said stripped nitrogen and methane to produce substantially pure nitrogen and substantially pure methane;

g. further cooling the remainder of the liquefied feed stream in a first subcooling step and in a second subcooling step;

h. expanding the subcooled feed stream and storing the same as LNG;

i. compressing a refrigerant gas in a plurality of steps;

j. splitting said compressed refrigerant gas into a major stream and a minor stream;

k. cooling said major stream in said first cooling step, said second cooling step, and said first subcooling step;

l. dividing said major stream into two further streams, liquefying one of said further streams in said second subcooling step, work expanding the other of said streams and passing the resulting cold gas through said second and first subcooling steps and returning said gas to be compressed;

m. cooling at least part of said minor stream by heat exchange with the liquefied hydrocarbons produced in steps (b) and (c);

n. expanding said minor stream, combining it with the substantially pure nitrogen from step (f) and passing the combined streams through said second cooling step to provide at least part of the refrigeration therefore; and

o. further expanding the warmed minor stream, combining the expanded minor stream with the other of said streams of step (l) and passing the so-combined streams through said second cooling step and first cooling step to provide at least part of the refrigeration therefore.

10. A process according to claim **9,** including cooling at least part of said minor stream with a Freon refrigeration cycle, combining said at least part with the part cooled in step (m).

11. A process according to claim **9,** including subcooling the substantially pure methane produced in step (f) in the first and second subcooling steps and directing the same to a methane storage facility.

12. A process according to claim **1,** including sweetening the stored LNG referred to in step (h) by injecting substantially pure methane into said LNG.

13. A process according to claim **9** including condensing the boil-off from the stored LNG by heat exchange with the liquefied further stream referred to in step (l), returning the condensed boil-off to the stored LNG.

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