United States Patent [19]

Markbreiter et al.

[11] **3,837,172**

[45] **Sept. 24, 1974**

[54] **PROCESSING LIQUEFIED NATURAL GAS TO DELIVER METHANE-ENRICHED GAS AT HIGH PRESSURE**

[75] Inventors: **Stephen J. Markbreiter**, Edison; **Irving Weiss**, Brooklyn, both of N.Y.

[73] Assignee: **Synergistic Services Inc.**, New York, N.Y.

[22] Filed: **June 19, 1972**

[21] Appl. No.: **263,983**

[52] **U.S. Cl.** **62/24**, 62/28, 62/38, 60/36

[51] **Int. Cl.** **F25j 3/02**

[58] **Field of Search** ..... 62/23, 24, 27, 28, 29, 62/41, 43, 50, 51, 52, 53, 40, 32, 34, 38, 44; 60/36, 59 T

[56] **References Cited**

UNITED STATES PATENTS

2,666,303	1/1954	Schuftan	62/43
2,763,138	9/1956	Tsunoda	62/40
2,823,523	2/1958	Eakin et al.	62/31
2,952,984	9/1960	Marshall	62/27
3,261,169	7/1966	Harmens	62/28
3,362,175	1/1968	Burns	62/28
3,383,873	5/1968	Becker	62/38
3,524,897	8/1970	Kniel	62/28
3,570,261	3/1971	Schwartzman	60/36

Primary Examiner—Norman Yudkoff
Assistant Examiner—F. Sever
Attorney, Agent, or Firm—Paul W. Garbo

[57] **ABSTRACT**

Liquefied natural gas is pumped to high pressure and divided into a major portion which is heated and introduced into a rectifying column and a minor portion which enters the column as subcooled reflux. Methane-enriched gas leaves the top of the column at high pressure while liquid ethane and heavier hydrocarbons are withdrawn from the bottom thereof. When the methane-enriched gas is to be delivered at a pressure above the critical pressure of the gas in the column, the heated major portion is expanded with the performance of work before being introduced into the column; the work thus performed is utilized to compress the methane-enriched gas to a pressure above that in the column.

10 Claims, 2 Drawing Figures

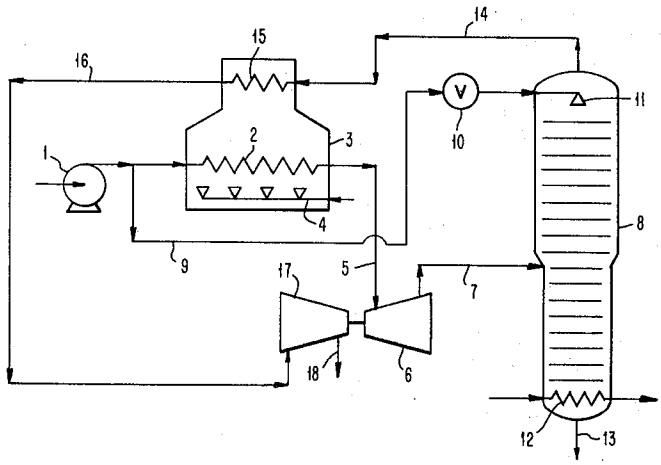


FIG. 1

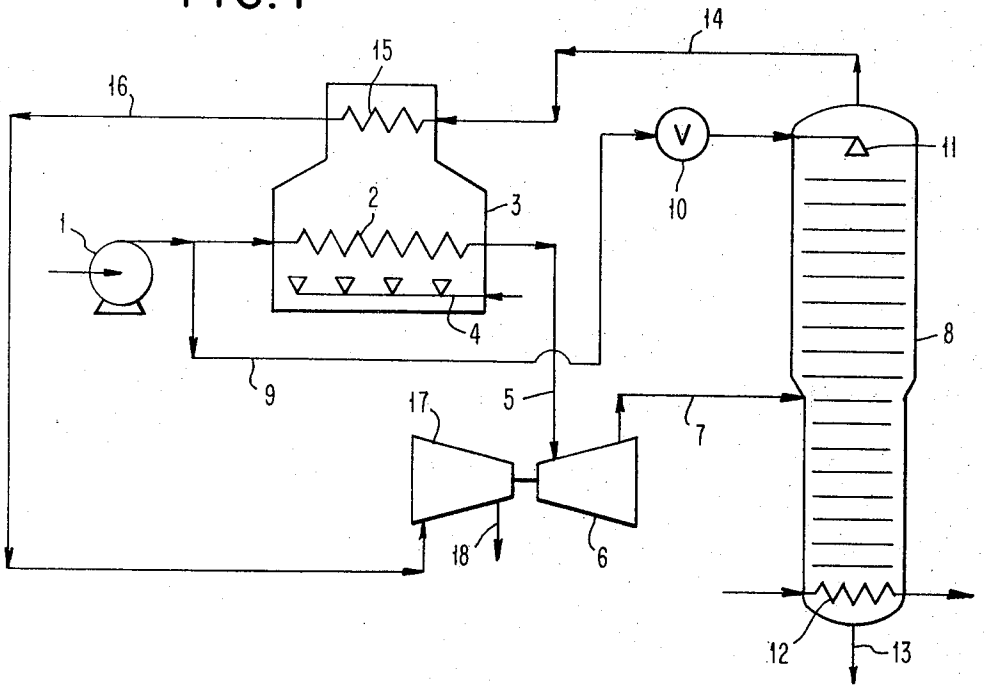
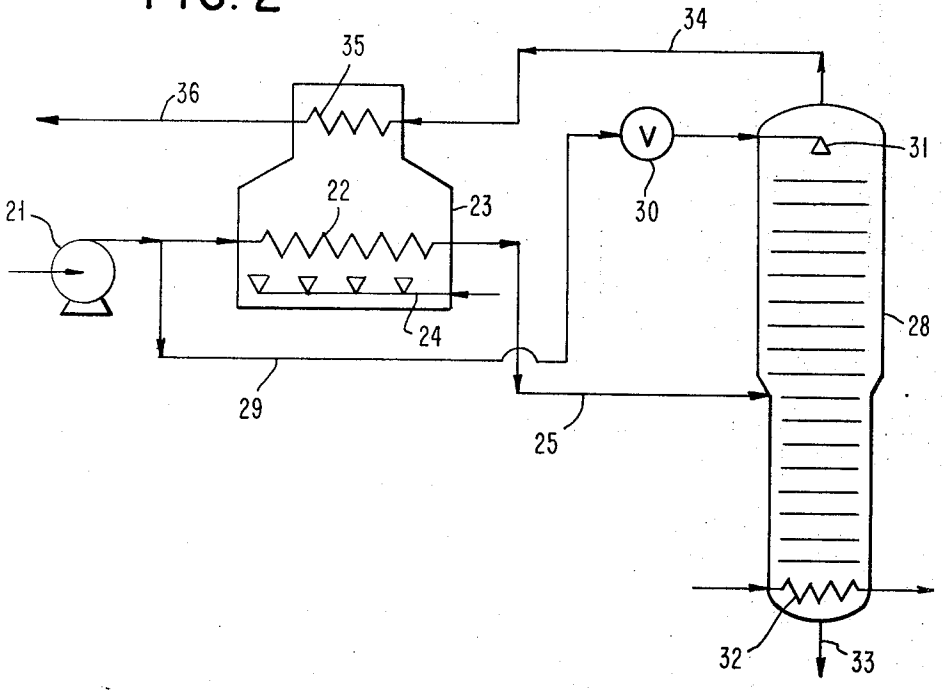

14
15
16
V
11
2
3
10
1
8
4
9
17
5
7
18
6
12
13

FIG. 2


34
35
36
V
31
22
23
30
21
28
24
29
25
32
33

PROCESSING LIQUEFIED NATURAL GAS TO DELIVER METHANE-ENRICHED GAS AT HIGH PRESSURE

BACKGROUND OF THE INVENTION

This invention relates to a process for separating ethane and heavier hydrocarbons from liquefied natural gas, hereinafter called LNG, to yield methane-enriched gas of predetermined heating value. More particularly, the invention relates to such process in which the desired separation is effected by pumping LNG to high pressure, vaporizing a major portion of the pressurized LNG and introducing it into the middle section of a rectification zone maintained at high pressure, while introducing a minor portion of the pressurized LNG into the top of the rectification zone as subcooled reflux liquid; methane-enriched gas is delivered at high pressure.

Numerous processes have been proposed for removing C_2 and higher hydrocarbons from LNG by rectification. However, with the growing trend of storing and transporting natural gas as a liquid that can be readily vaporized and injected into a pipeline system for distributing fuel gas of specified heating value, there has been increasing need to reduce the capital investment and operating cost of plants designed to revaporize LNG and deliver a methane-enriched gas of controlled heating value. The demand for such plants has grown with the increasing importation of LNG which must be made interchangeable with the domestic fuel gas in any given distribution system.

U.S. Pat. No. 2,952,984 granted to Marshall in 1960 discloses a process which appears to be simpler and more economical than the many other processes that have been previously proposed. Marshall pumps LNG into the middle of a high-pressure rectifying column and provides reflux liquid by condensing some of the vapors leaving the column by indirect heat exchange with the LNG flowing to the column. The Marshall process involves appreciable heat exchange equipment and piping, a vapor-liquid separator and a rectifying column of large diameter.

It is an object of this invention to simplify further the plant for separating C_2 and higher hydrocarbons from LNG and to make the operation more economical.

A further object is to provide a high-pressure system for delivering methane-enriched gas at a pressure above that in the rectifying column without using compression energy from an external source.

SUMMARY OF THE INVENTION

In accordance with this invention, LNG containing ethane, propane and heavier hydrocarbons is pressurized, a major portion of the pressurized LNG is vaporized by heating and is introduced into the middle section of a rectifying column maintained at high pressure, a minor portion of the pressurized LNG is discharged into the top of the column as subcooled reflux liquid, and the desired separation of ethane and heavier hydrocarbons from the LNG to yield a vapor overhead product of methane-enriched gas is achieved by controlling the reboil heat supplied to the bottom of the column in relation to the quantity of subcooled reflux liquid entering the top of the column. Liquid enriched in ethane and heavier hydrocarbons is withdrawn from the bottom of the column.

A feature of the invention is that LNG at substantially atmospheric pressure is rectified at an elevated pressure permitting the delivery of methane-enriched gas of desired heating value to a pressurized transmission or distribution pipeline system with a minimum consumption of power from an external source. Accordingly, the pressure maintained in the rectifying column is in each particular case determined in relation to the required delivery pressure of the methane-enriched gas supplied to the distribution system. In general, the higher the required delivery pressure of the gas is, the higher the pressure in the rectifying column is. However, the pressure in the column must be maintained slightly below the critical pressure in the gas in the column. For example, it is advisable to keep the maximum pressure in the column about **20** psi (pounds per square inch) or somewhat more below the critical pressure of the gas therein. The critical pressure is a function of the LNG composition and the desired composition of each of the two rectification product streams.

When the desired delivery pressure of the methane-enriched gas is close to or above the pressure in the rectifying column, the methane-enriched gas leaving the rectifying column is compressed with work performed by the expansion of the vaporized major portion of the pressurized LNG prior to its introduction into the column. As a practical matter, the maximum pressure in the rectifying column will fall in the range of about 500 to 550 psi gauge.

The composition of LNG can vary appreciably from one source to another but usually will contain at least 75 percent of methane on a molar or gas volume basis. More frequently, the methane content of LNG is at least 85 percent. Nitrogen and other gases with boiling points lower than that of methane are generally present in small proportions less than about 5 percent in total. Often, the total content of lower-boiling gases is less than 2 percent.

The total content of ethane, propane, butane and other hydrocarbons found admixed with methane in LNG will generally be at least 5 percent and may be as high as 25 percent. Of these hydrocarbons, ethane is usually the predominant one.

The minor portion of the pressurized LNG which, without being heated except for incidental heat leaks and heat caused by pumping LNG, is fed to the top of the rectifying column as subcooled reflux liquid is generally in the range of about 10 to 35 percent of the total LNG undergoing rectification. In most cases, the minor portion of LNG used as subcooled reflux liquid is in the range of about 15 to 25 percent of the LNG supplied to the rectifying column. Simplification of apparatus is achieved by supplying a minor portion of the pressurized LNG directly to the top of the rectifying column as reflux liquid in that the usual condenser, vapor-liquid separator and pump for returning liquid as reflux to the rectifying column are thereby eliminated. It is a further feature of the invention that the minor portion of the pressurized LNG entering the top of the rectifying column as reflux liquid is appreciably subcooled relative to the vapor leaving the top of the column. Generally, this reflux liquid is subcooled at least about 50°F. and preferably at least 100°F. below the temperature of the vapor leaving the top of the rectifying column. The larger the degree of subcooling of the reflux liquid is, the smaller is the minor portion or quantity of reflux liquid required to achieve the desired rectifica-

tion. This is clearly advantageous because the thus increased major portion of the pressurized LNG can be expanded to develop more work utilized in compressing the methane-enriched gas to a high pressure above rectification pressure.

The remaining major portion of the pressurized LNG is heated to a temperature corresponding to the temperature in the middle section of the rectifying column where the major portion is introduced. However, when the methane-enriched gas leaving the top of the column is to be supplied to a pipeline system operating at a pressure higher than that in the rectifying column, the major portion of the pressurized LNG is heated to a sufficiently high temperature that it can be both vaporized, and expanded in an engine or turbine with the performance of work and then be substantially at the temperature in the middle section of the rectifying column where the expanded gas is introduced. The work derived from the expansion of the vaporized major portion of the LNG is utilized to compress the methane-enriched gas that then is delivered to the pipeline system operating at a pressure higher than that in the rectifying column.

The LNG must be pressurized at least to a pressure sufficiently high to overcome the pressure drops encountered in its flow through the heater and piping and into the rectifying column which is usually maintained at a pressure above 100 psi gauge and more frequently above 300 psi gauge. Where the major portion of the pressurized LNG is to be expanded with the performance of work prior to being discharged into the column, the LNG is pumped to a higher pressure that not only overcomes the pressure drops already mentioned but also permits expansion of the vaporized LNG in an engine or turbine to produce the desired quantity of work for compressing the methane-enriched gas and introduction of the expanded vapor into the rectifying column maintained at a pressure slightly below the critical pressure of the gas therein. In other words, when the methane-enriched gas must be delivered to a distribution system operating at a pressure above the high pressure in the rectifying column, the LNG must be pumped to a sufficiently high pressure that the work performed in the expansion of the vaporized major portion of the LNG from pumping pressure to rectification pressure will equal the work required to compress the methane-enriched gas at rectification pressure to the higher pressure of the distribution system. The total pressure drop encountered by the LNG flowing through the heater and piping and into the rectifying column is generally in the range of about 30 to 60 psi. When vaporized LNG is expanded in an engine or turbine, the pressure is decreased by at least 200 psi but more often by at least 400 psi.

BRIEF DESCRIPTION OF THE DRAWINGS

In the further description which follows, reference is made to the accompanying drawings, of which:

FIG. **1** is a process diagram wherein LNG is subjected to rectification to yield methane-enriched gas and that gas is delivered at a pressure above that in the rectifying column; and

FIG. **2** is a process diagram wherein LNG is rectified to deliver methane-enriched gas to a distribution system operating at a pressure below that of the rectification.

DESCRIPTION OF PREFERRED EMBODIMENTS:

In FIG. **1**, LNG at a temperature of −255°F. is pressurized to 1,050 psi gauge and then divided so that **76%** of the LNG flows through vaporizing coil **2** in heater **3** provided with burner **4.** The heated vapor at a temperature of −10°F. and a pressure of **1000** psi gauge discharges through pipe **5** into turbo-expander **6** wherein the vapor is expanded to a pressure of 500 psi gauge and a temperature of −80°F. The expanded vapor leaves expander **6** containing a slight amount of liquid and flows through pipe **7** into the middle of rectifying column **8.**

The remaining 24 percent of the pressurized LNG at a temperature of −240°F. and a pressure of 1,050 psi gauge passes through pipe **9** and expansion valve **10** and discharges as subcooled reflux liquid through nozzle **11** in the top of column **8.** A heating medium, such as steam, is passed through heating coil **12** in the bottom of column **8** to reboil the liquid collecting in the bottom at a temperature of 80°F. This liquid which is principally ethane with a minor proportion of propane and heavier hydrocarbons is withdrawn from column **8** through pipe **13** as a valuable feed for a conventional separation plant recovering ethane and propane in high purities.

Methane-enriched gas leaves the top of column **8** through pipe **14** at a temperature of −120°F. and a pressure of 500 psi gauge and flows through coil **15** in the top of heater **3.** The gas at a temperature of −20°F. and a pressure of 475 psi gauge passes through pipe **16** to turbo-compressor **17** which is coupled to and driven by turbo-expander **6.** Compressor **17** delivers the methane-enriched gas to pipe **18** at a pressure of 600 psi gauge and a temperature of 20°F.

The separation which is achieved by the foregoing rectification is shown by the following tabulated percentage compositions on a molar or gas volume basis:

	LNG	Methane-Enriched Gas	Bottom Liquid
N_2	0.20	0.21	0.00
CH_4	90.60	97.28	0.82
C_2H_6	7.70	2.48	77.92
C_3H_8+	1.50	0.03	21.26

The bottom liquid amounts to only 7 percent of the LNG on a molar basis and the methane-enriched gas constitutes the remainder of the LNG supplied to the rectifying column. The heating value of the LNG is 1,093 BTU/SCF (British Thermal Units per standard cubic foot), while that of the methane-enriched gas is 1,025 BTU/SCF.

Using the same LNG described in connection with FIG. **1** as the feed to pump **21** of FIG. **2,** the LNG is pumped to a pressure of 550 psi gauge and a temperature of −240°F. The pressurized LNG is divided so that 76 percent flows through coil **22** in heater **23** provided with burner **24.** The resulting vapor issuing from coil **22** at a temperature of −80°F. flows through pipe **25** into the middle section of rectifying column **28** in which a pressure of **500** psi gauge is maintained. The remaining **24%** of the pressurized LNG flows through pipe **29** and expansion valve **30** and discharges through nozzle **31** in the top of column **28.** Heating fluid is passed through coil **32** in the bottom of column **28.** A valuable bottom

liquid is withdrawn from column **28** through pipe **33.**

Methane-enriched gas leaves the top of column **28** through pipe **34** at a temperature of −120°F. After passing through coil **35** in heater **23,** the gas at ambient temperature flows into pipeline **36** operating at a pressure of 475 psi gauge.

The separation achieved in FIG. **2** is the same as that already described in connection with FIG. **1.** The essential differences between the processes just described are the delivery of gas at a pressure of 600 psi gauge in FIG. **1** and at a pressure of 475 psi gauge in FIG. **2,** while the horsepower consumed by the pump of FIG. **1** is approximately double that consumed by the pump of FIG. **2.**

Many variations and modifications of the invention will be apparent to those skilled in the art without departing from the spirit or scope of the invention. For example, two pumps might be used in FIG. **1**; one pump could pressurize all of the LNG just sufficiently to permit the minor portion thereof to flow into the top of the column while a second smaller pump could further raise the pressure of only the major portion to **1050** psi gauge required for passage of the major portion through coil **2** and turbo-expander **6** into column **8.** Accordingly, only such limitations should be imposed on the invention as are set forth in the appended claims.

What is claimed is:

1. A process for producing methane-enriched gas at high pressure by rectification of liquefied natural gas supplied at substantially atmospheric pressure and containing a minor portion of C_2 and higher hydrocarbons which comprises pressurizing said liquefied natural gas, heating a major portion of the pressurized liquefied natural gas to effect vaporization and introducing the vaporized natural gas into the middle section of a rectifying column at high pressure, introducing an unheated minor portion of at least 10 percent of said pressurized liquefied natural gas into the top of said rectifying column as subcooled reflux liquid, and withdrawing said methane-enriched gas at high pressure from the top of said rectifying column.

2. The process of claim **1** wherein the unheated minor portion is not more than about 35 percent of the pressurized liquefied natural gas and is introduced into the top of the rectifying column as reflux liquid subcooled at least 50°F. below the temperature of the methane-enriched gas withdrawn from the top of said rectifying column.

3. The process of claim **1** wherein the high pressure in the rectifying column is in the range of about 500 to 550 psi gauge.

4. The process of claim **3** wherein the liquefied natural gas is pressurized so that at least the major portion thereof attains a pressure at least 200 psi higher than the high pressure in the rectifying column, said major portion, after being heated to effect vaporization and before being introduced into said rectifying column, is expanded with the performance of work, and said performance of work is utilized to compress the methane-enriched gas withdrawn from the top of said rectifying column to a pressure higher than the high pressure in said rectifying column.

5. The process of claim **4** wherein the unheated minor portion is in the range of about 15 to 25 percent of the pressurized liquefied natural gas and is introduced into the top of the rectifying column as reflux liquid subcooled at least 100°F. below the temperature of the methane-enriched gas withdrawn from the top of said rectifying column.

6. In the process of separating C_2 and higher hydrocarbons from methane in liquefied natural gas wherein said liquefied natural gas is pumped to a high pressure, heated and introduced into the middle section of a rectifying column at high pressure, the improvement which comprises passing an unheated minor portion of at least 10 percent of said liquefied natural gas pumped to a high pressure into the top of said rectifying column as reflux liquid subcooled at least about 50°F. below the temperature of the vapor leaving the top of said rectifying column.

7. The process of claim **6** wherein the unheated minor portion is in the range of about **15** to **25%** of the liquefied natural gas pumped to a high pressure.

8. The process of claim **6** wherein the unheated minor portion is not more than about 35 percent of the liquefied natural gas pumped to a high pressure and passes into the top of the rectifying column at a pressure above 300 psi gauge.

9. Apparatus for processing liquefied natural gas supplied at substantially atmospheric pressure by rectification at high pressure and for delivering methane-enriched gas resulting from said rectification at an increased pressure, comprising pumping means for pressurizing said liquefied natural gas, a vaporizing coil connected to the discharge of said pumping means and to the inlet of a turbo-expander coupled to a turbo-compressor, a rectifying column, a pipe connected to the discharge of said turbo-expander and to the middle section of said column, a valved pipe connected to the discharge of said pumping means and to the top of said column forming a by-pass of said vaporizing coil and said turbo-expander, and a warming coil connected to the top of said column and to the inlet of said turbo-compressor.

10. The apparatus of claim **9** wherein the vaporizing coil and the warming coil are disposed in the same heating chamber.

* * * * *