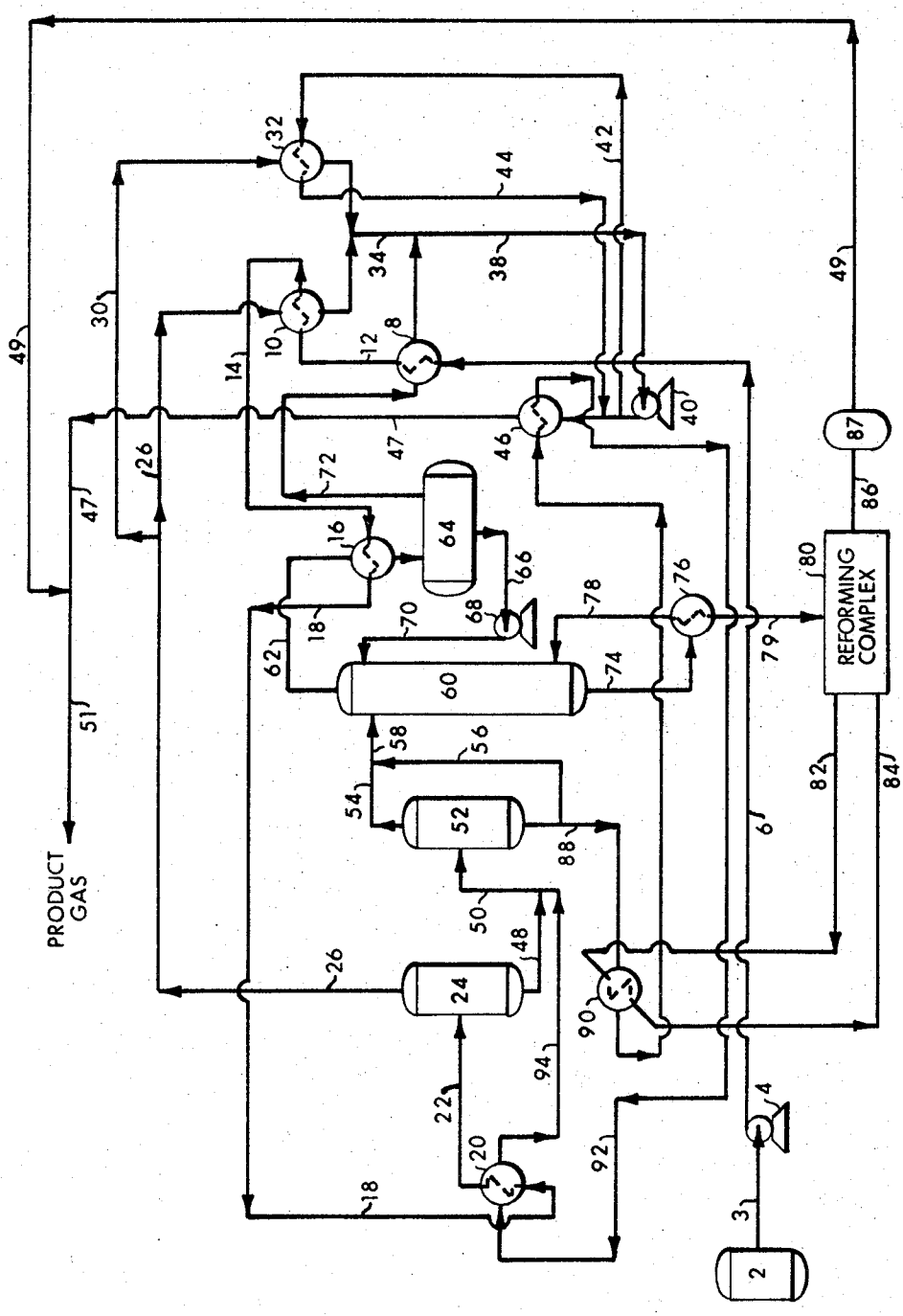
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REGASIFICATION OF A LIQUEFIED GASEOUS MIXTURE

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REGASIFICATION OF A LIQUEFIED GASEOUS MIXTURE

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ABSTRACT OF THE DISCLOSURE

This invention provides a method for the regasification and pressurization of condensed low temperature gaseous mixtures by a heat integration scheme which maximizes the use of the "cold" in the liquid to be regasified and pressurized. This heat integration scheme, as opposed to the use of separate heat transfer media, results in substantial economic advantages in that more economical heat exchange equipment can be used, no separate handling facilities are needed for an intermediate heat transfer media and losses normally accompanying the use of intermediate heat transfer media are eliminated. The heat integration scheme makes possible the elimination of compressors and minimizes the pumping equipment used to increase the pressure of the regasified mixture.

Background of the invention

The instant invention relates generally to a method of heating low temperature fluids. More particularly, the process of the instant invention provides a method for heating low temperature fluids by employing a heat integration scheme which maximizes the use of the "cold" in the fluid being heated and which results in the minimization of investment and operating costs. The teachings of the instant invention are particularly applicable to the regasification of liquefied natural gas (hereinafter referred to as LNG).

Natural gas is often available in areas remote to where it will be ultimately used. Quite often the source of this fuel is separated from the point of utilization by a large body of water, in which case it may prove necessary to effect bulk transfer of the natural gas by large marine tankers designed for such transport. Under these circumstances, economics dictate that the natural gas be liquefied so as to greatly reduce its volume and that it be transported at essentially atmospheric pressure. Under these conditions the LNG is at a temperature of approximately —258° F. This temperature represents the boiling point of methane at atmospheric pressure. It is to be noted, however, that the LNG often contains amounts of heavier hydrocarbons, such as ethane, propane, butane and the like. These will vary the boiling range of the LNG so that it usually will fall somewhere between —240° F. and —258° F. However, nitrogen, which may also be present, can cause the low end of the temperature range to approach temperatures as low as —270° F.

When the LNG arrives at the point of utilization, it is, of course, in liquefied form, and it becomes necessary to regasify it before it is used as a fuel. In addition, it may prove necessary to adjust the heating value of the natural gas to conform to local requirements prior to its entrance into the actual fuel distribution system. Where this is required, adjustment may be conveniently achieved by use of a reforming operation of the type to be more fully discussed hereinafter. It may also become necessary to increase the pressure of the regasified product from atmospheric pressure to the distribution pipeline pressure, which in some cases may be as high as 1000 p.s.i.a.

It will be appreciated that the reconversion of the LNG to a gaseous form requires the addition of a substantial amount of heating. When heating cryogenic streams such as LNG, many problems both of an economic and technical nature are often encountered. For example, when heating such streams, direct heat exchange is only feasible with heating streams which are dry, since any moisture present would freeze out and deposit and would eventually block or plug the heat exchangers employed. Coupling this with the fact that the least expensive heat sources are wet (e.g., water, steam, air and flue gas), it is not surprising that problems in this area are often encountered. In the past problems of this nature have been solved by using a separate intermediate heat exchange fluid contained in a closed cycle or the like. The function of this type of intermediate fluid system is to absorb heat from a hot wet heat source and inject it to the cold LNG stream. However, there are numerous economic disadvantages which accompany the use of such a system. For example, heat exchanger area requirements are in effect doubled since the number of needed exchangers are usually as high. Furthermore, separate facilities are required to store, handle and possibly produce the separate intermediate exchange fluid.

In contrast, the teachings of the instant invention provide a method for heating cryogenic fluids such as LNG, which avoids the above mentioned difficulties. Thus, utilization of the method to be herein described in further detail results in substantial reductions in heat exchange costs and eliminates need for separate handling facilities. Also the need to make up losses in the amount of intermediate heat exchange media is avoided.

Summary of the invention

According to the instant invention, the above highly desirable results may be achieved by using recycled process streams in place of an intermediate heat exchange fluid. In a preferred embodiment of the invention, the LNG regasification is accomplished in combination with a reforming operation of a type known in the art and to be hereinafter discussed. In a preferred embodiment of the instant invention a cold liquid LNG stream is warmed by being passed through a series of heat exchangers, which exchangers serve to condense overhead vapors from a flashing drum and a distillation column (the column serving to effect the separation of C_3+ constituents from the lighter constituents of the natural gas). Upon its passage through this series of heat exchangers, the entering LNG is then heat exchanged with a portion of the bottoms from a second flashing drum and then enters the first flashing drum as feed. A portion of the bottoms from the second drum is passed in heat exchange with one or more hot streams available from the reforming operation. The overhead from the second flashing drum and the remaining portion of the bottoms product from said drum are combined and passed to the fractionating column. The bottoms of this column, comprising C_3 and heavier hydrocarbons, are fed to the reforming operation, as will be further discussed hereinafter. The top products from the tower are passed in heat exchange with the LNG as hereinbefore indicated and the condensed liquids are recycled into the upper region of the column. The uncondensed vapors are also passed in a second heat exchange with the LNG (which serves to warm the latter) and are then pumped up to suitable pipeline pressures. Following this increase in pressure, these materials are passed in heat exchange with the overhead vapors from the first drum and then are fed into a suitable gas distribution system.

Accordingly, an important object of the invention is to provide an efficient method for heating a cold fluid

without the need for separate intermediate heat exchange media.

Another important object of this invention is to facilitate the regasification of LNG so that it is in suitable condition for delivery and use as a fuel.

Still another object is to provide a system which allows the use of more economical heat exchange equipment and no separate intermediate heat transfer fluid facilities, thereby effecting substantial economies in equipment cost.

Yet another object is to provide a system which allows the use of lower pressure heat exchange equipment in the initial LNG heating, and which requires fewer pumps needed to effect the desired pipeline pressure.

Another object is to minimize operating costs in bringing the LNG from atmospheric pressure to the relatively high pipeline pressure.

Other objects and a fuller understanding of the invention may be had by referring to the following description and claims taken in conjunction with the accompanying drawing.

Brief description of the drawing

In the drawing a flow diagram illustrating a process according to the present invention is shown.

Referring to the drawing in detail, reference numeral **2** designates a stationary insulated storage tank which receives the LNG at atmospheric pressure from a tanker (not shown). The LNG in tank **2** will normally have a temperature of about −240° F. to −260° F. and may have, for example, the composition ranges shown in Table I.

TABLE I

Constituent:	Mole percent
C_1	60–70
C_2	15–25
C_3	8–15
C_4	2–4
C_5	0–1
C_6+	0–1

The LNG from tank **2** is fed through the line **3** into pump **4** wherein its pressure is increased to from about 14.7 to about 500 and preferably about 450 p.s.i.a. The pump **4** causes the pressurized LNG stream to flow via the lines **6, 12, 14** and **18** through a series of heat exchangers **8, 10, 16** and **20,** to be further discussed hereinafter. Upon exiting from exchanger **20** via the line **22,** the LNG stream has been heated to a temperature in the range of −30° F. to −70° F. and preferably around −58° F. The heated LNG stream is then fed into a first flashing drum **24.** Drum 24 may be operated in the range of 300 to 500 p.s.i.a. with a preferable range of from about 350 to about 400 p.s.i.a. The flashed vapors from drum **24** will be mostly methane and will have a composition range such as shown in Table II. This composition will, of course, depend on the composition of the initial feedstock and the exact temperature and pressure of the drum **24.**

TABLE II

Constituent:	Mole percent
C_1	80–95
C_2	5–15
C_3	0–3
C_4	0–1
C_5	0–.1
C_6	0

From drum **24** these vapors are fed via conduit **26** through heat exchanger **10.** A portion of the vapors from drum **24** branch off into conduit **30** and are fed through heat exchanger **32.** Vapors in exchanger **10** serve to warm the entering LNG in line **12.** The splitting of the overhead from flashing drum **24** into conduits **26** and **30** insures that the temperature approaches in heat exchangers **10** and **32** do not fall below allowable limits. Upon exit from exchangers **10** and **32,** the overhead is merged in line **34** and has a temperature in the range of from about −140° F. to about −170° F. (depending on the composition of the overhead from drum **24** and the feed composition to the plant) and preferably at about −160° F. The material in line **34** is then combined with the fractionator overhead which has been condensed and pumped from about 320 p.s.i.a. to 380 p.s.i.a. After combining the effluent streams from exchangers **8, 10** and **32,** resulting in a combined stream pressure in the range of 350 to 450 p.s.i.a. and more preferably about 380 p.s.i.a. and in a temperature in the range of −140° F. to −180° F. (about 10° F. below the stream bubble point) depending on the stream composition, the material in line **38** is pumped up to a pressure in a range of 900 to 1100 p.s.i.a. and preferably about 1000 p.s.i.a. by pump **40.** This high pressure stream is then used to make possible the condensation of the overhead vapors from drum **24** in exchanger **32.** Upon exit from exchanger **32,** they are conducted via the line **44** through heat exchanger **46,** which exchanger serves to vaporize and superheat the methane rich product gas so that when combined with the reformed gas in line **49** gives a suitable pipeline temperature in the range of 32° F. to 104° F. and preferably 50° F. Upon exiting from exchanger **46** via the line **47** the material is at about 1000 p.s.i.a. and at about 5° F. according to the preferred embodiment. This material has a composition as indicated in Table III.

TABLE III

Constituent:	Mole percent
C_1	70–80
C_2	20–25
C_3	0–5
C_3+	0–.5

The material in line **47,** which when combined with the reformed product in line **49,** is at suitable pipeline distribution conditions and is fed from the line **51** to a suitable distribution network (not shown).

Returning once again to drum **24,** the bottom products leaving drum **24** via the line **48** and having a temperature of approximately −58° F., are combined with part of the bottoms from drum **52.** The combined stream serves as a heat transfer media in a pump-around circuit. The combined stream in line **50,** having a temperature of approximately 50° F., is fed to drum **52.** The feed to drum **52** has a composition in the ranges indicated in Table IV below.

TABLE IV

Constituent:	Mole percent
C_1	18–25
C_2	25–35
C_3	18–25
C_4	9–15
C_5 and C_5+	2–5

Drum **52** is operated at a pressure of from about 300 to about 450 p.s.i.a. and preferably about 380 p.s.i.a. A portion of the bottoms leaving drum **52** (called the pump-around) is conducted via the line **88** through exchanger **90,** wherein it is heated by passing it in heat exchange with a hot reformate stream entering exchanger **90** via the line **82** and exiting exchanger **90** via the line **84.** Upon exit from exchanger **90,** said portion of the bottoms from drum **52** is conducted via line **91** through exchanger **46,** where the methane rich gas is vaporized. Upon leaving exchanger **46,** the pump-around is conducted via line **92** through exchanger **20,** where it serves to further heat the incoming LNG feed. Upon exit from exchanger **20,** this bottom fraction is combined with the bottoms from drum **24** and introduced via the line **50** back into drum **52.**

The remaining portion of the bottoms from drum **52** are combined with the products leaving the top of drum **52** via the line **54,** and this recombined stream is then fed via the line **58** into a fractionating column **60.** Tower **60** effects the separation of C_3- and C_3+ constituents. The C_3+ material leaves the bottom of the tower via the line **74** and enters reboiler **76.** A portion of the material en-

tering reboiler **76** is reintroduced into the bottom of the tower via the line **78**. The remaining portion of the bottoms from column **60** leaves reboiler **76** via the line **79** and is then fed to a reforming complex indicated as **80**. The material entering reforming complex **80** has a composition as indicated in Table V below.

TABLE V

Constituent:	Mole percent
C_1	0
C_2	0
C_3	60–70
C_4	20–30
Others	5–15

In the reforming operation this composition is converted so that the reformate will have a composition as indicated in Table VI.

TABLE VI

Constituent:	Mole percent
CO_2	3–7
CO	1–2
H_2	20–30
CH_4	60–70

A great deal of water, comprising about 50 percent of the molar flow, will also be present. This water is removed (in suitable apparatus not shown) after the reformate gas is heat exchanged with the portion of the bottoms from drum **52** as hereinbefore discussed. After this heat exchange, the reformate gas is ultimately fed via the line **86** to a compressor **87** where its pressure is raised to approximately 1000 p.s.i.a. The material leaving compressor **87** is then fed via the line **49** into the product gas line **51**.

Example.—Starting with a typical LNG feedstock composed of

TABLE VII

Constituent:	Mole percent
C_1	68
C_2	19
C_3	10
C_4	2
C_6	1

and operating in the aforesaid preferred temperature and pressure ranges, the following table indicates the approximate temperatures, pressures and stream compositions present at various locations in the depicted process. These locations are designated by referring to their assigned reference numerals appearing in the figure.

1. A process for regasifying a feed of liquefied gas comprising the following steps in combination:

(a) pressurizing and heating said liquefied gas feed;

(b) flashing said feed into a first flashing drum;

(c) passing the bottoms from said first drum to a second flashing drum;

(d) drawing off a portion of the stream from the bottom of said second drum;

(e) heating said portion by use of an external process stream;

(f) passing the heated portion resulting from step (e) in heat exchange with the incoming liquefied gas feed to said first drum; and then

(g) combining said portion with said bottoms from said first drum and passing the resulting combined stream into said second drum.

2. The process of claim **1** wherein the heating in step (a) is partially accomplished by utilizing heat from the materials leaving the top of said first flashing drum.

3. The process of claim **1** wherein said first drum is operated at a pressure in the range of from about 300 to about 500 p.s.i.a. and said second drum is operated in a range of from about 300 to about 450 p.s.i.a.

4. The process of claim **1** wherein said liquefied gas is liquefied natural gas and said external process stream is a hot reformate gas stream obtained by reforming the heavy ends of said natural gas.

5. In a process of the type wherein a liquefied natural gas feed is regasified, fractionated and subjected in part to a reforming operation, the improvement which comprises the following steps in combination:

(a) pressurizing said liquefied natural gas feed;

(b) heating the pressurized feed resulting from step (a) by passing it in heat exchange relationship with internal process streams;

(c) flashing the resulting pressurized and heated feed in a first flashing drum;

(d) passing the bottom products from said first drum to a second drum;

(e) drawing off a portion of the stream from the bottom of said second drum;

(f) heating said portion by passing it in heat exchange relationship with a hot process stream from said reforming operation;

(g) passing the heated portion resulting from step (f) in heat exchange relationship with said natural gas feed to further heat said feed; and

(h) combining said portion with the bottom product from said first drum being fed to said second drum.

TABLE VIII

Location	Temperature (° F.)	Pressure (p.s.i.a.)	Typical stream composition (mole percent)									
			C_5	C_2	C_3	C_4	C_5	C_6	CO_2	N_2	CO	H_2
Line 6	−250	450	68	19	10	2		1				
Line 14	−85	425	68	19	10	2		1				
Line 22	−58	400	68	19	10	2		1				
Line 26	−58	400	85	13	2							
Line 48	−58	400	25	35	26.5	11.5	1.5	.5				
Line 58	50	380	25	35	26.5	11.5	1.5	.5				
Line 62	−15	355	36	55	9							
Line 79	160	360			57.5	31.5	10	1				
Line 51	50	1,000	74.2	11.8	1.7	.17	.005		1.4		.92	9.6

It is to be understood that the foregoing arrangement can be modified in various details and need not necessarily be restricted to the processing of natural gas, per se. The flow diagram and description are given by way of example for the purposes of illustrating more clearly how the invention may be performed. Moreover, the operating percentages, temperatures and pressures specified hereinabove can be varied considerably for given mixtures. Accordingly, reference should be had to the following appended claims in determining the full scope of the invention.

What is claimed is:

6. The process of claim **5** further characterized in that the heating in step (a) is accomplished by passing the entering natural gas feed in heat exchange relationship with process streams resulting from the fractionation of said natural gas feed.

7. The process of claim **6** wherein the overhead from said first flashing drum is also passed in heat exchange relationship with the entering natural gas feed.

8. The process of claim **7** wherein said liquefied natural gas feed is pressurized to about 450 p.s.i.a., said first drum is operated at a pressure in the range of about 400 p.s.i.a.

and said second drum is operated in a pressure in the range of about 380 p.s.i.a.

9. An improved process for heating and regasifying a liquefied hydrocarbon gaseous feed which comprises, pressurizing said feed, flashing said pressurized feed in a first flashing drum, utilizing the overhead from said drum to heat the incoming feed, passing the bottoms from said drum to a second drum, passing a portion of the bottoms product from said second drum in heat exchange with an external process stream whereby said portion is heated and utilizing said heated portion to further heat said incoming feed.

10. The process of claim **9** wherein vapors from the top of said second drum and the remaining part of the bottoms from said second drum are combined and fractionated in a C_3 and heavier cut and a C_3 and lighter cut, with the C_3 and lighter cut being passed in heat exchange with said pressurized feed.

11. The process of claim **10** wherein the overhead from said first drum is split into a first sidestream and a second sidestream, said first sidestream being passed in heat exchange relationship with said incoming feed and said second sidestream being passed in heat exchange relationship with vapors from said C_3 and lighter cut.

References Cited

UNITED STATES PATENTS

3,251,191	5/1966	Reed	62—45
3,331,214	7/1967	Proctor et al.	62—52

LLOYD L. KING, *Primary Examiner.*

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62—52