United States Patent [19]

Arenson

[11] **3,771,260**

[45] **Nov. 13, 1973**

[54] **METHOD OF VAPORIZING AND COMBINING A LIQUEFIED CRYOGENIC FLUID STREAM WITH A GAS STREAM**

[75] Inventor: **Edwin M. Arenson,** Oklahoma City, Okla.

[73] Assignee: **Black, Sivalls & Bryson, Inc.,** Oklahoma City, Okla.

[22] Filed: **Jan. 29, 1970**

[21] Appl. No.: **6,889**

[52] **U.S. Cl.** ..... **48/190,** 48/180 R, 48/180 P, 48/191, 48/196 R, 137/90, 261/16, 261/39, 261/79 A, 261/118, 261/130, 261/131, 261/141, 431/166

[51] **Int. Cl.** **B05b 7/00,** F17d 1/04

[58] **Field of Search** ..... 48/190, 191, 196, 48/180; 261/16, 39, 129–131, 141, 79 A, 118; 137/3, 6, 90, 98; 431/166; 60/36, 39.05, 39.46, 39.71

[56] **References Cited**

UNITED STATES PATENTS

1,922,573	8/1933	Dunkak	137/90 X
3,257,180	6/1966	King	48/190 X
3,014,705	12/1961	Colucci	261/16
2,767,025	10/1956	Griffith	261/39 X
2,609,282	9/1952	Haug et al.	48/190 X
3,074,783	1/1963	Paull	48/196 X
2,097,771	11/1937	Nelson	431/DIG. 67
2,522,026	9/1950	Evans	48/196 X
2,737,965	3/1956	Newman	137/90
3,417,563	12/1968	Loprete	60/39.71 X
3,517,510	6/1970	Melenric	60/39.71 X
3,689,237	9/1972	Stark et al.	48/190

FOREIGN PATENTS OR APPLICATIONS

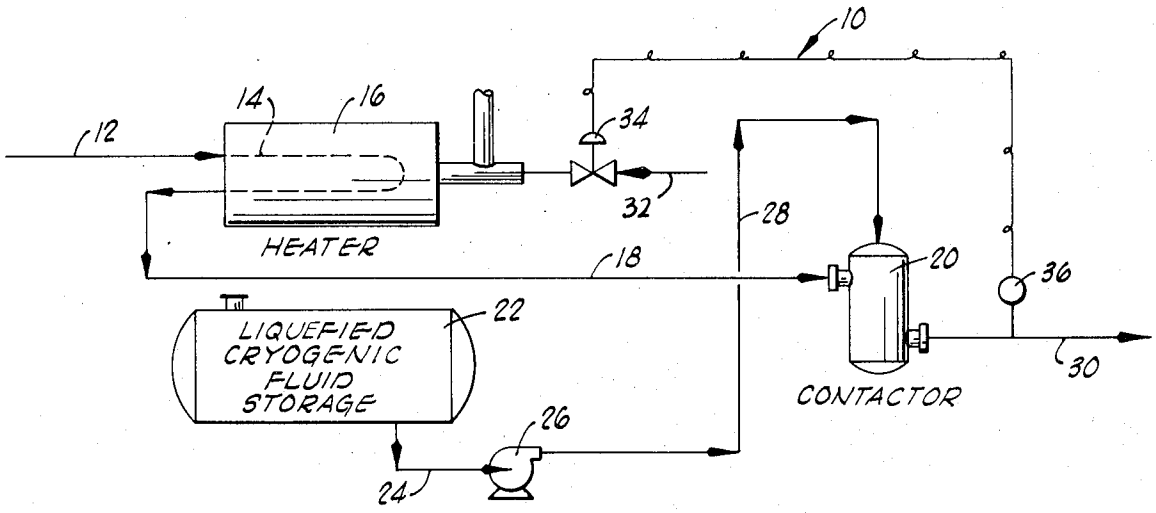
1,158,934	7/1969	Great Britain	48/190

Primary Examiner—Joseph Scovronek
Attorney—Dunlap, Laney, Hessin & Dougherty

[57] **ABSTRACT**

The present invention relates to methods of vaporizing and combining a stream of liquefied cryogenic fluid with a gas stream. The gas stream is heated, and the liquefied cryogenic fluid stream is injected directly into the heated gas stream and intimately contacted therewith so that the cryogenic fluid is vaporized and combined with the gas stream.

5 Claims, 4 Drawing Figures



PATENTED NOV 13 1973

3,771,260

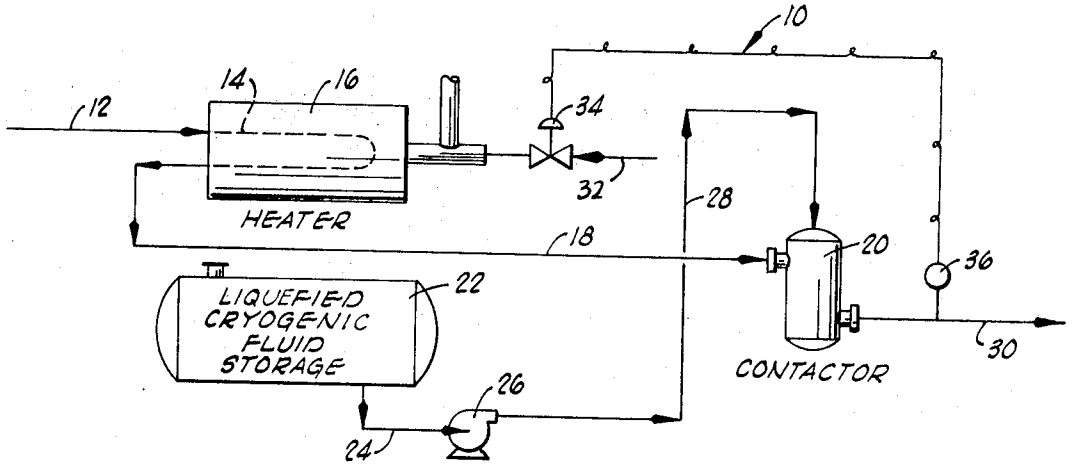


FIG. 1

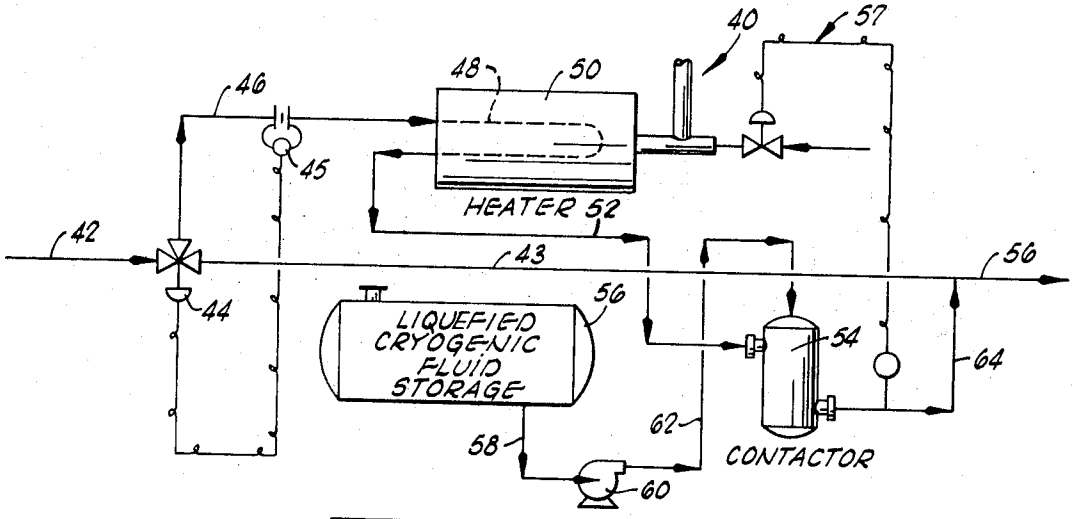


FIG. 2

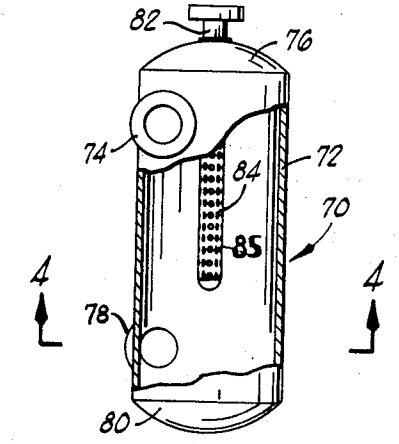


FIG. 3

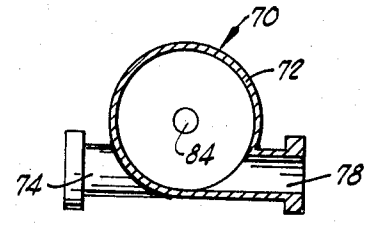


FIG. 4

INVENTOR
EDWIN M. ARENSON

BY
Dunlap, Laney, Hessin & Dougherty
ATTORNEYS

METHOD OF VAPORIZING AND COMBINING A LIQUEFIED CRYOGENIC FLUID STREAM WITH A GAS STREAM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to methods of vaporizing and combining a stream of liquefied cryogenic fluid with a gas stream, and more particularly, but not by way of limitation, to a method and system for vaporizing and combining a stream of liquefied cryogenic fluid with a gas stream wherein the liquefied cryogenic fluid is injected directly into the gas stream.

2. Description of the Prior Art

Cryogenic fluids are those fluids which can exist in a liquid state only at very low temperatures. In many applications such fluids are stored in the liquid state, and when needed, the fluids are vaporized and combined with other gas streams. For example, cryogenic fluids such as liquefied petroleum gas (LPG) and liquefied natural gas (LNG) are commonly used in the supply and distribution of natural gas for carrying out a process commonly known as "Peak Shaving." Peak shaving processes are used in areas where natural gas is not locally produced and must be transported by pipeline from remote producing fields. Such pipelines are generally designed for a gas capacity equal to the normal consumption in the area of use. Consequently, during periods of peak gas consumption, such as a prolonged cold spell, the demand for natural gas exceeds the capacity of the pipeline. When this condition exists, the stored LNG or LPG is vaporized, superheated to prevent subsequent condensation, and injected into the pipeline in order to meet the demand.

A common peak shaving process presently being used by natural gas producing and distribution companies utilizes LNG. The natural gas pipeline system for continuously transporting a supply of natural gas from remote producing fields to the area of use is sized for a gas capacity between the minimum demand during the summer months and the peak demand during the winter months. A refrigeration system is installed at the area of use, and during the summer months the excess natural gas transported by the pipeline is refrigerated so that it is liquefied, and stored. During the winter months the stored liquiefied natural gas is revaporized, superheated and injected into the pipeline so that the peak natural gas demand is met.

Heretofore, various types of heating apparatus have been used to preheat, vaporize and superheat LPG or LNG prior to combining it with the gas transported through the pipeline system. For example, fluid heaters of the direct fired type which utilize natural gas as fuel have been used successfully. In addition, heating apparatus of the indirect type which utilize an intermediate heating fluid, such as isopentane or water, have been used successfully. In the indirect type of apparatus the heating fluid is heated by a natural gas fired heater and circulated through heat exchangers wherein heat is transferred to the LPG or LNG causing it to be vaporized and superheated.

In the peak shaving processes used heretofore the liquefied cryogenic fluid is vaporized and superheated prior to combining it with the gas stream. As a result, special materials of construction are required in the heating apparatus which are compatible with the low temperatures encountered. For example, LNG exists in the liquid state at a temperature of approximately −260° F, and as a result, expensive materials such as stainless steel or aluminum must be used in the parts of the heating apparatus exposed to LNG in order to prevent thermal stress failures. Furthermore, many problems are associated with the design and operation of heating apparatus used to vaporize and superheat liquefied cryogenic fluids. Specifically, problems relating to static and dynamic flow instability, two-phase flow and vapor binding are commonly encountered and difficult to overcome.

By the present invention methods of vaporizing and combining a liquefied cryogenic fluid stream with a gas stream are provided wherein expensive and elaborate cryogenic fluid heating apparatus is not required and the problems relating to the use of prior heating apparatus for vaporizing and superheating liquefied cryogenic fluid are not encountered.

SUMMARY OF THE INVENTION

The present invention relates to methods of vaporizing and combining a liquefied cryogenic fluid stream with a gas stream comprising the steps of heating the gas stream, injecting the liquefied cryogenic fluid stream directly into the heated gas stream and intimately contacting the liquefied cryogenic fluid stream with the heated gas stream so that the cryogenic fluid is vaporized and combined with the gas stream.

It is, therefore, a general object of the present invention to provide methods of vaporizing and combining a liquefied cryogenic fluid stream with a gas stream.

A further object of the present invention is the provision of methods of vaporizing and combining a liquefied cryogenic fluid stream with a gas stream for transport to a point of use wherein expensive and elaborate heating apparatus for vaporizing and superheating the cryogenic fluid is not required.

Yet a further object of the present invention is the provision of methods of vaporizing and combining a liquefied cryogenic fluid stream with a gas stream whereby heretofore encountered operating and design problems associated with flow instability, two-phase flow and vapor binding are eliminated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view of a system for carrying out the method of the present invention,

FIG. 2 is a diagrammatic view of an alternate system for carrying out the method of the present invention,

FIG. 3 is a top view, partially in section of a contactor apparatus which may be employed in accordance with the present invention, and

FIG. 4 is a view in cross section of the apparatus of FIG. 3 taken along line 4—4 thereof.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring particularly to FIG. 1, a system for carrying out the method of the present invention, generally designated by the numeral 10, is illustrated in diagrammatic form. The system 10 basically comprises an inlet conduit 12 for reciving a gas stream. The conduit 12 is connected to the heating coil 14 of a conventional gas stream heater 16. The gas stream heater 16 may be any suitable conventional gas fired heating apparatus. Heaters of the type described and claimed in U. S. Pat. No. 2,993,479 have been found to be particularly suit-

able. While passing through the heating coil 14 of the heater 16, the gas stream is heated a predetermined amount. From the heater 16 the heated gas stream is led by a conduit 18 to a contactor apparatus 20.

A conduit 24 is connected to a conventional storage tank 22 containing a reservoir of liquefied cryogenic fluid. A stream of liquefied cryogenic fluid is conducted by the conduit 24 from the storage tank 22 to a conventional pump 26. The discharge of the pump 26 is connected to a conduit 28 which leads the stream of liquefied cryogenic fluid to an inlet connection provided in the contactor apparatus 20. As will be described further hereinbelow, the contactor apparatus 20 is of a design such that the stream of liquefied cryogenic fluid entering the apparatus through conduit 28 is mixed with and intimately contacted by the heated gas stream entering the apparatus through conduit 18. As a result of the intimate contact brought about by the contactor apparatus 20, heat is transferred to the liquefied cryogenic fluid causing it to be varporized and combined with the gas stream. The combined cryogenic fluid and gas stream leaves the contactor apparatus 20 through a conduit 30 from where it is conducted to a point of distribution or use.

A source of fuel is conducted to the heater 16 by a conduit 32. A conventional fuel control valve 34 is disposed in the conduit 32, and a conventional temperature controller 36 is operably connected to the control valve 34. The temperature controller 36 senses determines and is responsive to the temperature of the combined cryogenic fluid and gas stream passing through the conduit 30 and regulates the fuel control valve 34 accordingly.

Referring now to FIG. 2, an alternate system for carrying out the method of the present invention is illustrated, generally designated by the numeral 40. The system 40 basically comprises an inlet conduit 42 for receiving a gas stream. The inlet conduit 42 is connected to a three-way flow control valve 44. One of the outlet ports of the three-way valve 44 is connected to a conduit 46 and the other outlet port is connected to a conduit 43. A conventional flow control device 45 operably connected to the control valve 44 is disposed in the conduit 46. The flow control device 45 senses and is responsive to the flow rate of gas passing through conduit 46 and regulates control valve 44 accordingly. The conduit 46 leads a portion of the gas stream from the three-way valve 44 to the heating coil 48 of a conventional heater 50. The portion of the gas stream passing through the heating coil 48 is heated a predetermined amount, and leaves the heater 50 by way of a conduit 52 connected to a contactor apparatus 54. A conduit 58 conducts a stream of liquefied cryogenic fluid from a conventional storage tank 56 to a conventional pump 60. The discharge of the pump 60 is connected to a conduit 62 which leads the stream of liquefied cryogenic fluid to an inlet connection in the contactor apparatus 54. The contactor apparatus 54 brings about intimate contact between the liquefied cryogenic fluid entering the contactor apparatus by way of conduit 62 and the heated portion of the gas stream entering the contactor apparatus through conduit 52. Heat from the heated portion of the gas stream entering the contactor apparatus 54 is transferred to the stream of liquefied cryogenic fluid causing it to be vaporized and mix with the gas stream. The combined cryogenic fluid and gas stream is led from the contactor apparatus 54 by a conduit 64 which is connected to the conduit 43. The combined stream of cryogenic fluid and gas from conduit 64 is combined with the portion of the gas stream passing through conduit 48, and the total combined stream passes into a conduit 56 from where it is conducted to a point of use or distribution.

Referring now to FIGS. 3 and 4, a preferred contactor apparatus for use in the systems illustrated in FIGS. 1 and 2 is shown, generally designated by the numeral 70. It will be understood that the contactor apparatus 70 is illustrative of the contactor apparatus 20 (FIG. 1) and contactor apparatus 54 (FIG. 2), described above. The contactor apparatus 70 basically comprises a closed cylindrical container 72 having a tangential gas stream inlet connection 74 at the forward end 76 thereof and a tangential outlet connection 78 at the rearward end 80 thereof. The inlet connection 74 and outlet connection 78 are positioned generally perpendicularly to the axis of the container 72. A liquefied cryogenic fluid connection 82 is attached to the forward end 76 of the container 72, and a length of pipe 84 having a plurality of perforations or openings 85 therein is disposed within the container 72 on a line coinciding with the axis of the container 72. One end of the perforated pipe 84 is attached to the connection 82 and the other end is closed by a cap or the like.

OPERATION

In operation of the system illustrated in FIG. 1, a gas stream, such as a natural gas stream transported by a pipeline, is conducted to the heating coil 14 of the heater 16 by the inlet conduit 12. As the gas stream passes through the heating coil 14, a predetermined quantity of heat is transferred thereto. The particular quantity of heat required will depend on various factors, but generally a quantity of heat equal to that required to vaporize the stream of liquefied cryogenic fluid and superheat it to the desired combined stream outlet temperature is transferred to the gas stream. The heated gas stream then passes through conduit 18 into the contactor apparatus 20 where it intimately contacts the stream of liquefied cryogenic fluid entering contactor apparatus 20 through conduit 28. While within the contactor apparatus 20, heat is transferred from the gas stream to the liquid cryogenic fluid causing the cryogenic fluid to be vaporized and mixed with the gas stream. Temperature controller 36 senses the temperature of the combined cryogenic fluid and gas stream passing through the conduit 30 and functions to regulate fuel control valve 34. That is, if the temperature of the stream passing through conduit 30 is below a preselected desired temperature, fuel control valve 34 is opened thereby causing more fuel to enter the burner of the heater 16 which in turn causes more heat to be transferred into the gas stream passing through the heating coil 14 thereof. Conversely, if the temperature of the stream passing through the conduit 30 is higher than the preselected temperature, fuel control valve 34 is closed thereby reducing the heat transferred to the gas stream. Thus, the rate of flow of the liquefied cryogenic fluid being vaporized and combined with the gas stream may be increased or decreased as desired and the temperature controller 36 automatically causes the amount of heat being transferred to the gas stream to be increased or decreased proportionally.

The system illustrated in FIG. 1 is used where the rate of the gas stream being porcessed is relatively low.

However, where a stream of liquefied cryogenic fluid is to be added to a gas stream of high volume rate, the system illustrated in FIG. 2 is preferred. As will be understood by those skilled in the art, the particular gas stream volume rate at which the system of FIG. 2 should be used instead of the system of FIG. 1 will depend on economic considerations relating to the apparatus required.

In operation of the system illustrated in FIG. 2, the gas stream entering the system 40 through the inlet conduit 42 is divided into two portions by the three-way valve 44. Three-way valve 44 may be any conventional flow control valve operably connected to the conventional flow control device 45 disposed in conduit 46. The flow control device 45 regulates three-way valve 44 so that a predetermined flow rate of gas is passed through conduit 46. The particular flow rate of gas passed through conduit 46 will depend on various factors such as the flow rate of liquefied cryogenic fluid to be vaporized, the desired combined stream outlet temperature, etc. Conventional engineering calculations understood by those skilled in the art may be employed to determine optimum flow rates, temperatures, and sizes of apparatus required. The portion of the gas stream passing through conduit 46 is conducted to the heating coil 48 of the heater 50 by the conduit 46. As the gas stream passes through the heating coil 48, heat is transferred thereto. The heated portion of the gas stream then passes into contactor apparatus 54 by way of conduit 52. While within contactor 54, the heated portion of the gas stream intimately contacts the stream of liquefied cryogenic fluid entering contactor apparatus 54 thereby vaporizing the cryogenic fluid and causing it to be combined with the gas stream. The combined cryogenic fluid and gas stream pass out of the contactor apparatus 54 through conduit 64 and are mixed with the portion of the gas stream passing through conduit 43. A temperature controller and fuel control valve assembly, generally designated by the numeral 57, may be used to automatically control the amount of fuel combusted in the heater 50 in the same manner as described above for the heater 16.

As will be understood by those skilled in the art, any of a variety of conventional control systems may be used with the systems of the present invention to automatically control the rate of liquefied cryogenic fluid vaporized, the heating of the gas stream, etc.

In operation of the contactor apparatus illustrated in FIGS. 3 and 4, the heated gas stream enters the container 72 through the tangential inlet connection 74 thereof. Liquefied cryogenic fluid enters the perforated pipe 84 through the connection 82 and is sprayed into the container 72 through the perforations 85 thereof. Because of the tangential inlet and outlet connections 74 and 78, the heated gas stream entering the container 72 follows a generally spiral path adjacent to the walls of the container 72 as it travels from the forward end 76 thereof to the rearward end 80 thereof. Thus a high degree of turbulence is imparted to the heated gas stream as it passes through the container 72. The stream of liquefied cryogenic fluid sprayed into the container 72 through the perforations 85 of the pipe 84 is intimately contacted by the turbulent heated gas stream within the container 72, and as a result, heat is transferred from the heated gas stream to the cryogenic fluid causing the cryogenic fluid to be vaporized and mixed with the gas stream. The combined cryogenic fluid vapors and gas stream leave the contactor apparatus 70 through the outlet connection 78 thereof. While the contactor apparatus described herein is preferred for use in the present invention, it will be understood that any contactor apparatus which will bring about intimate contact between the heated gas stream and the liquefied cryogenic fluid stream may be employed.

The contactor apparatus used in accordance with the present invention must be constructed from materials compatible with the low temperatures of cryogenic fluids. However, considerably less of such materials are required than that required for heretofore used heating apparatus. Furthermore, the gas stream heater employed in the present invention may be of a conventional type and design, and since low temperatures and two-phase flow are not encountered therein, operation problems are reduced to a minimum.

As will be understood, the methods and systems of the present invention may be used for vaporizing and combining any liquefied cryogenic fluid with any gas stream. However, the present invention is particularly suitable for vaporizing and combining liquefied cryogenic fluids such as LNG or LPG with natural gas streams in carrying out peak shaving operations. For example, a stream of natural gas at a pressure of 400 psia. and a temperature of 40° F. may be heated to a temperature of 340° F. thereby adding heat to the gas stream in the amount of 181 BTU per pound of the gas stream. A stream of LNG at a temperature of −260° F. requires a heat input of 358 BTU per pound to vaporize and superheat it to a temperature of 40° F. Thus, 1.98 pounds of gas heated to 340° F. are required to vaporize and combine 1 pound of LNG therewith. For a natural gas stream of 30 MMSCFD at a pressure of 400 psia. and a temperature of 40° F., a conventional heater capable of adding approximately 10 million BTU/HR of heat to the gas stream may be employed in a system of the present invention to vaporize and combine a 28,900 lb./HR stream of LNG therewith resulting in a combined natural gas stream of approximately 45 MMSCFD at a temperature of 40° F.

Other advantages of the present invention as compared to heretofore use methods and systems wherein the liquefied cryogenic fluid is varporized and superheated in heating apparatus prior to being combined with the gas stream are as follows:

1. The contactor apparatus of the present invention may be located in the same vicinity as the liquefied cryogenic fluid storage tank and pump thereby obviating the need for long liquefied cryogenic fluid pipelines. In prior methods and systems, the heating apparatus for vaporizing and superheating the cryogenic fluid must be located remotely from the storage tank and pump to safeguard against fires or explosions thereby requiring long pipelines for conducting the liquefied cryogenic fluid to the heating apparatus.
2. The liquefied cryogenic fluid pump required in a system of the present invention is smaller and less expensive than that required in heretofore used systems since pressure loss associated with cryogenic fluid vaporizing and superheating apparatus is not encountered.
3. If the pressure of the gas stream is reduced from a relatively high pressure to a low pressure level at the location where the liquefied cryogenic fluid is vaporized and combined with the gas stream, the

heating apparatus of the present invention may be installed upstream of the pressure reduction means with the contactor apparatus of the present invention installed downstream thereof, thereby reducing the size and cost of apparatus required as compared to heretofore used systems. For example, if the gas stream is conducted by a pipeline system at a pressure of 400 psia. and then reduced to a pressure level of 20 psia. for distribution, the gas stream may be heated at 400 psia. and the liquefied cryogenic fluid vaporized and combined with the gas stream at a pressure of 20 psia. As will be understood by those skilled in the art, this arrangement will require smaller heating apparatus and a smaller liquefied cryogenic fluid pump as compared to heretofore used systems wherein the liquefied cryogenic fluid is vaporized, superheated and combined with the gas stream at 400 psia.

4. If the temperature of the gas stream prior to being heated is higher than the required combined stream temperature, the systems of the present invention will require less total heat input than prior systems since some of the original heat content of the gas stream will be utilized to vaporize and superheat the liquefied cryogenic fluid.

The present invention, therefore, is well adapted to carrying out the objects and attain the ends and advantages mentioned, as well as those inherent therein. While presently preferred embodiments of the invention are given for the purpose of disclosure, numerous changes can be made which will readily suggest themselves to those skilled in the art and which are encompassed within the spirit of the invention disclosed herein.

What is claimed is:

1. A method of vaporizing and combining a stream of liquefied cryogenic fluid with a gas stream being transported through a pipeline to apoint of use comprising the steps of:

heating said gas stream to a temperature such that a quantity of heat is added thereto substantially equal to the heat required to vaporize said stream of liquefied cryogenic fluid and superheat it to the desired temperature of the combined stream of cryogenic fluid and gas;

injecting said stream of liquefied cryogenic fluid directly into said heated gas stream;

intimately contacting said stream of liquefied cryogenic fluid with said heated gas stream so that the cryogenic fluid is vaporized, superheated and combined with said gas stream;

determining the temperature of the combined stream of cryogenic fluid and gas; and

automatically controlling the heating of said gas stream in predetermined relation to the temperature of said combined stream so that the liquid cryogenic fluid is vaporized and superheated and a combined stream of cryogenic fluid and gas having the desired temperature is produced in said pipeline.

2. The method of claim 1 wherein the gas stream is natural gas.

3. The method of claim 2 wherein the liquefied cryogenic fluid is liquefied natural gas.

4. The method of claim 2 wherein the liquefied cryogenic fluid is liquefied petroleum gas.

5. A method of vaporizing and combining a stream of cryogenic liquefied natural gas with a natural gas stream being transported through a pipeline to a point of use comprising the steps of:

dividing the natural gas stream into first and second portions;

heating the first portion of said natural gas stream so that a quantity of heat is added thereto substantially equal to the heat required to vaporize said stream of cryogenic liquefied natural gas and superheat it to the desired temperature;

injecting said stream of cryogenic liquefied natural gas directly into the heated first portion of said natural gas stream;

intimately contacting said stream of cryogenic liquefied natural gas with the heated first portion of said natural gas stream so that the cryogenic liquefied natural gas is vaporized, superheated and mixed with the first portion of said natural gas stream;

determining the temperature of the resulting combined first portion of natural gas;

automatically controlling the heating of the first portion of said natural gas stream in predetermined relation to the temperature of the resulting combined first portion of natural gas so that said cryogenic liquefied natural gas is vaporized and superheated and a combined first portion of natural gas having the desired temperature results; and

combining the second portion of said natural gas stream with the combined first portion of said natural gas stream.

* * * * *