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

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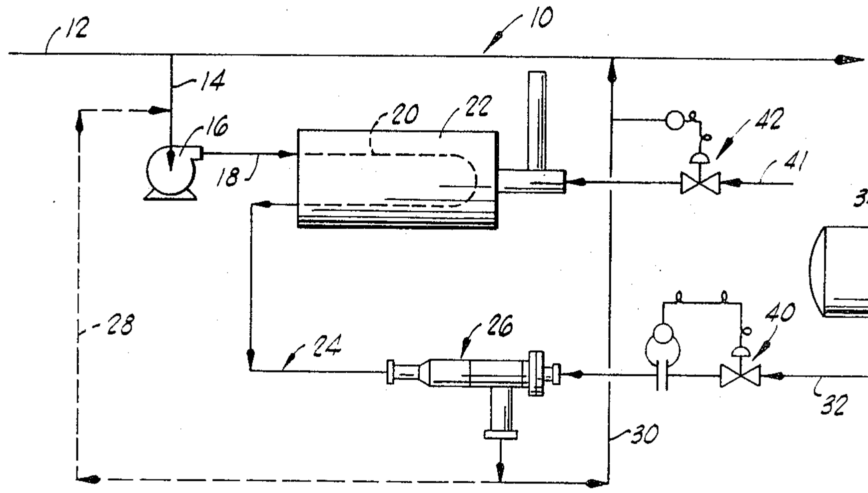

FIG. 1

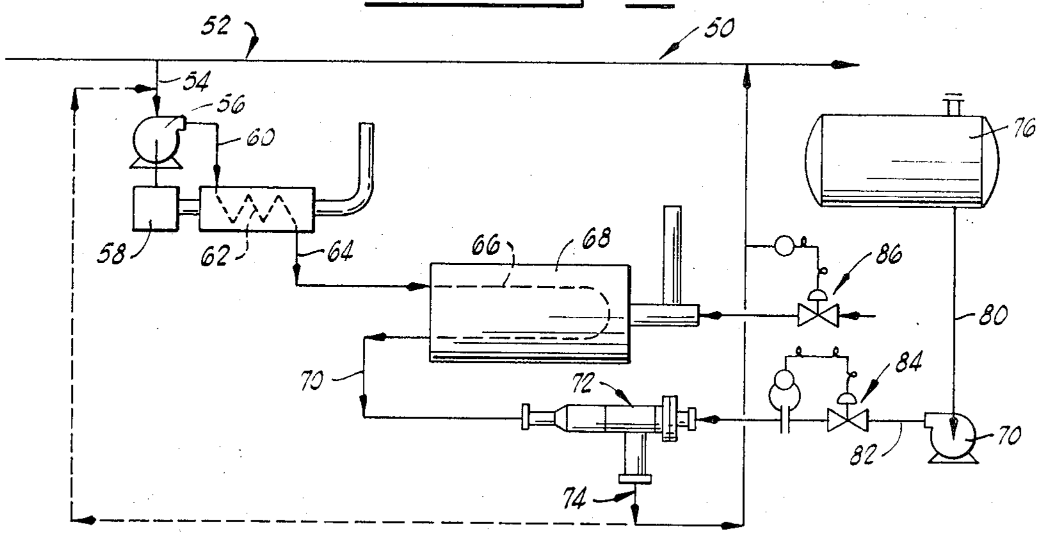

FIG. 2

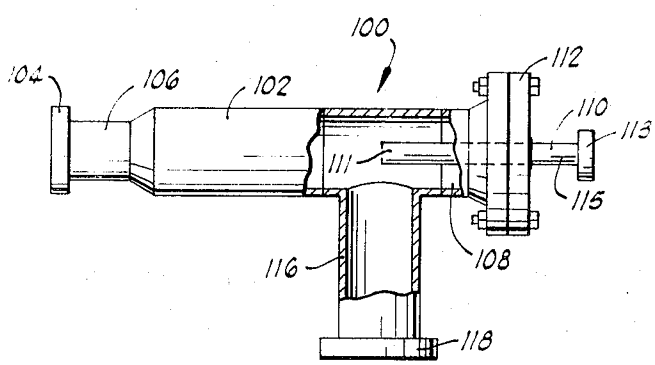

FIG. 3

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

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Continuation-in-part of application Ser. No. 6,889, Jan. 29, 1970. This application Oct. 6, 1970, Ser. No. 78,504
The portion of the term of the patent subsequent to Nov. 13, 1990, has been disclaimed
Int. Cl. F17d *1/04*
U.S. Cl. 48—190 6 Claims

ABSTRACT OF THE DISCLOSURE

The present invention relates to an improved method of vaporizing and combining a stream of liquefied cryogenic fluid, such as liquefied natural gas, with a gas stream, such as natural gas. The gas stream is divided into first and second portions, and the pressure of the first portion is elevated an amount sufficient to cause it to pass through a heating circuit and recombine with the second portion of the gas stream. The first portion of the gas stream is heated within the heating circuit, and the stream of liquefied cryogenic fluid to be vaporized and combined with the gas stream is injected directly into the heated first portion within the heating circuit so that the liquefied cryogenic fluid is vaporized and mixed with the first portion of the gas stream. The resulting mixture of vaporized cryogenic fluid and the first portion of the gas stream is then combined with the second portion of the gas stream.

CROSS-REFERENCES TO RELATED APPLICATIONS

This application is a continuation-in-part of application Ser. No. 6,889 filed Jan. 29, 1970.

BACKGROUND OF THE INVENTION

(1) Field of the invention

The present invention relates generally to an improved method of vaporizing and combining a stream of liquefied cryogenic fluid with a gas stream, and more particularly, but not by way of limitation, to an improved method of 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 exist in a liquid state only at very low temperatures. In many applications, such fluids are stored in the liquid state, and when they are 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 known as "Peak Shaving." Peak shaving processes are used in areas where natural gas is not locally produced and as a result must be transported by pipeline from remote producing fields. Such pipelines are generally designed for a natural gas capacity below that required during peak consumption periods in the area of use. Consequently, during such periods, e.g., prolonged cold spells, the demand for natural gas exceeds the capacity of the pipeline. When this condition exists, the stored LPG or LNG is vaporized, superheated and combined with the natural gas stream to increase the total volume of gas available for use.

A common peak shaving process presently being used by the 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 in the area of use, and during the summer months the excess natural gas transported by the pipeline is refrigerated, liquefied and stored. During the winter months the stored liquefied natural gas is revaporized, superheated and combined with the pipeline natural gas so that the peak natural gas demand is met. Heretofore, various types of heating apparatus have been used to preheat, vaporize and superheat LNG prior to combining it with the gas transported through the pipeline system. Such heating apparatus generally require special materials of construction due to the low temperatures encountered. For example, LNG exists in liquid state at a temperature of approximately —260° F. and as a result, stainless steel or aluminum must be used in the parts of the heating apparatus exposed to the LNG in order to prevent thermal stress failures thereof.

In my copending application, Ser. No. 6,889 filed Jan. 29, 1970, methods are disclosed for vaporizing and combining a liquefied cryogenic fluid stream with a gas stream wherein the use of expensive cryogenic fluid heating apparatus is obviated. Specifically, the gas stream is injected directly into the heated gas stream and intimately contacted therewith thereby causing the cryogenic fluid stream to be vaporized and combined with the gas stream. While these methods are generally highly satisfactory, the resulting combined gas stream is obtained at a substantially lower pressure level than the pressure level of the gas stream prior to combining the cryogenic fluid therewith. That is, a substantial overall drop in the gas stream pressure level is experienced. In certain applications, a pressure reduction of the gas stream constitutes a disadvantage in that additional gas stream compressor horsepower is required to overcome the pressure reduction which constitutes a substantial increase in the operating cost of the pipeline system.

By the present invention, an improved method of vaporizing and combining a liquefied cryogenic fluid stream with a gas stream is provided whereby a substantial gas stream pressure drop is not encountered.

SUMMARY OF THE INVENTION

The present invention relates to an improved method of vaporizing and combining a liquefied cryogenic fluid stream with a gas stream comprising the steps of dividing the gas stream into first and second portions, elevating the pressure of the first portion an amount sufficient to cause it to pass through a heating circuit and recombine with the second portion of said gas stream without incurring a substantial drop in said gas stream, heating the first portion of the gas stream within the heating circuit, injecting the stream of liquefied cryogenic fluid directly into the heated first portion of the gas stream within the heating circuit so that the liquefied cryogenic fluid is vaporized and mixed with the first portion, and combining the mixture of the first portion of the gas stream and vaporized cryogenic fluid with the second portion of the gas stream.

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

A further object of the present invention is the provision of an improved method 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 obviated and wherein an overall pressure reduction of the gas stream does not result.

Other and further objects, features and advantages of the invention will be apparent from the following detailed description thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view of the 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, and

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

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings, and particularly to FIG. 1, a system for carrying out the improved method of the present invention is illustrated, generally designated by the numeral **10**. The system **10** basically comprises a conduit **12** for receiving and conducting a gas stream. The conduit **12** may be the main pipeline through which a gas stream is transported to a distribution system or other ultimate destination, or the conduit **12** may be an ancillary pipeline connected to the main pipeline, and through which all or part of the gas stream may be caused to pass during periods when a liquefied cryogenic fluid stream is to be vaporized and combined therewith.

A conduit **14** is connected to the conduit **12** and connected to a conventional gas compressor or blower **16**. The discharge of the gas compressor **16** is connected by a conduit **18** to the heating coil **20** of a conventional gas heater **22**. The heater **22** may be any suitable conventional gas stream heater, but preferably in a gas fired heater of the type described and claimed in U.S. Pat. No. 2,993,479. A conduit **24** is connected to the discharge of the heating coil **20** of the heater **22** and to the inlet of a contactor apparatus, generally designated by the numeral **26**. As will be described further hereinbelow, the contactor apparatus **26** is of a design such that a stream of liquefied cryogenic fluid entering the apparatus through a conduit **32** connected thereto is mixed with and intimately contacted by a heated gas stream entering the apparatus **26** through conduit **24**. The resultant mixture is withdrawn from the apparatus **26** through a conduit **30** connected to the outlet of contactor apparatus **26**. The conduit **30** is connected to the conduit **12** at a point downstream of the conduit **14**. For convenience, the conduits **14, 18, 24** and **30**, and the compressor **16**, heater **22** and contactor apparatus **26** of the system **10** is referred to herein as the "heating circuit."

A conventional cryogenic fluid storage tank **34** is provided, and a conduit **36** connects the storage tank **34** to a liquefied cryogenic fluid pump **38**, which may be any conventional pump suitable for pumping low temperature cryogenic fluids. The discharge of the pump **38** is connected to the conduit **32** which is in turn connected to the contactor apparatus **26** of the heating circuit of the system **10**.

In operation of the system **10** illustrated in FIG. 1, a gas stream, to which vaporized cryogenic fluid is to be combined, is passed through the conduit **12** and a portion of the gas stream flows from the conduit **12** into the heating circuit of the system **10** through the conduit **14** attached thereto. The compressor **16** may be any conventional gas compressor or blower which will pump a predetermined volume of gas through the heating circuit of the system **10**, and simultaneously raise the pressure thereof a predetermined amount. Specifically, the compressor **16** is of a design and type which raises the pressure of the gas stream an amount sufficient to cause it to flow through the heating circuit of the system **10** without incurring an overall pressure drop in the gas stream. For example, assuming that the pressure level of the gas stream passing through the conduit **12** is 500 p.s.i.g. and the pressure drop of a predetermined volume of gas passing through the heating circuit is 10 p.s.i., the compressor **16** is designed to elevate the pressure of the volume of gas to a level of approximately 510 p.s.i.g. Thus, by reason of the compressor **16**, a portion of the gas stream passing through the conduit **12** may be caused to flow through the heating circuit of the system **10** without incurring a substantial pressure reduction in the gas stream.

The storage tank **34** contains a reservoir of liquefied cryogenic fluid. A stream of liquefied cryogenic fluid is conducted from the tank **34** by the conduit **36** to the pump **38**. The discharge of the pump **38** is led by a conduit **32** to the cryogenic fluid inlet connection of the contactor apparatus **26**. As will be understood, the cryogenic fluid pump **38** is of a design such that the pressure level of the stream of liquefied cryogenic fluid passing into conduit **32** is elevated to a level so that it is injected into the contactor apparatus **26** through the cryogenic fluid inlet connection thereof. A conventional flow control assembly **40** is disposed in the conduit **32** for controlling the flow of liquefied cryogenic fluid passing into the contractor apparatus **26**.

The portion of the gas stream passing through the heating circuit of the system **10** is heated by the heater **22** a predetermined amount. Specifically, a quantity of heat is transferred to the gas stream which is equal to the quantity of heat required to vaporize the stream of liquefied cryogenic fluid entering the contactor apparatus **26** and superheat the vaporized cryogenic fluid to a desired combined stream temperature. The heated gas stream passes through the conduit **24** into the contactor apparatus **26** where it intimately contacts liquefied cryogenic fluid injected therein. While within contactor apparatus **26**, heat is transferred from the heated gas stream to the liquefied cryogenic fluid causing it to be vaporized and mixed with the gas stream. The mixture then passes from the contactor apparatus **26** into the conduit **30**. The mixture is led by the conduit **30** into the conduit **12** where it is combined with the remaining portion of the inlet gas stream passing therethrough. A conventional temperature controller and fuel control valve assembly **42** is provided which senses the temperature of the gas mixture passing through the conduit **30** and functions to regulate the quantity of fuel passing through a conduit **41** which is connected to the burner or burners (not shown) associated with the heater **22**. That is, if the temperature of the gas mixture passing through the conduit **30** is below a preselected desired temperature, additional fuel is caused to enter the burner of heater **22** which in turn causes more heat to be transferred into the gas stream passing through the heating coil **20** thereof, and vice versa. 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** will automatically cause the amount of heat being transferred to the gas stream to be increased or decreased proportionately.

The particular flow rate of gas passed into the heating circuit of the system **10** will depend on various factors such as the flow rate of liquefied cryogenic fluid to be vaporized, the desired combined stream outlet temperature, and optimum economics relating to the system. As will be understood, conventional engineering calculations may be employed to determine optimum flow rates, temperatures and sizes of apparatus required.

Referring now to FIG. 2, an alternate system for carrying out the improved method of the present invention is illustrated, generally designated by the numeral **50**. The system **50** is similar to the system **10** shown in FIG. 1 and includes a conduit **52** for receiving and conducting a gas stream to which a stream of liquefied cryogenic fluid is to be combined. The system **50** further includes a heating circuit comprised of a conduit **54** which is connected to a conduit **52** and to a compressor or blower **56**. The compressor or blower **56** is driven by a conventional gas turbine **58**. A conduit **60** connects the discharge of the blower **56** to a coil **62** which is disposed in heat exchange relationship with the exhaust gases generated in the gas turbine **58**. A conduit **64** connects the outlet of the heat exchanger coil **62** to a heating coil **66** disposed within a conventional gas fired heater **68**. The discharge of the heating coil **66** of the heater **68** is connected by a conduit **70** to a contactor apparatus of the same type and design described above, generally designated by the numeral **72**. The discharge connection of the contactor apparatus **72** is connected to a conduit **74** which is in turn connected to the conduit **52** at a point downstream of the conduit **54**.

A liquefied cryogenic fluid storage tank **76** is provided connected to a conventional liquefied cryogenic fluid pump **78** by conduit **80**. The discharge of the pump **78** is connected to the contacting apparatus **72** by conduit **82**. A liquefied cryogenic fluid flow control assembly generally designated by the numeral **84** is provided for controlling the rate of flow of liquefied cryogenic fluid to the contactor apparatus **72**, and a conventional temperature controller and fuel control valve assembly **86** is provided which functions in the same manner as the temperature controller and fuel valve assembly **42** described above.

The system illustrated in FIG. 2 operates in the same manner as the system illustrated in FIG. 1 and described above except that the blower **56** is driven by a conventional gas turbine **58**. As will be understood by those skilled in the art, a gas turbine produces a large volume of hot exhaust gases which are normally vented to the atmosphere. In the system illustrated in FIG. 2, these exhaust gases are passed in heat exchange relationship with the gas stream passing through the heating circuit of the system **50** prior to passing the gas stream into the heating coil **66** of heater **68**. Thus, the gas stream is preheated in the heat exchanger coil **62** and then heated further in heating coil **66** of the heater **68**. In applications of the present invention where electric power is not available or other economic factors dictate the use of gas as a source of power for driving the compressor **56**, the use of the system **50** is economically advantageous.

In both of the systems illustrated in FIGS. 1 and 2 and described above, a portion of the mixture of the gas stream and vaporized cryogenic fluid from the heating circuit may be recycled through the heating circuit. That is, referring to FIG. 1, a conduit **28** may be provided connected to the conduit **30** and connected to the conduit **14** upstream of the compressor **16**. This arrangement is particularly advantageous in applications where large volumes of liquefied cryogenic fluids are to be vaporized and combined with a relatively small gas stream.

Referring now to FIG. 3, a contactor apparatus generally designated by the numeral **100** is illustrated in detail. As will be understood, the contactor apparatus **100** is identical to the contactor apparatus **26** and **72** shown in FIGS. 1 and 2 and described above. While various types of contactor apparatus may be employed in the present invention, such as the apparatus disclosed in my copending application Ser. No. 6,889 filed Jan. 29, 1970, it has now been found that a contactor apparatus of the type shown in FIG. 3 is highly effective and economically manufactured. The contactor apparatus **100** basically comprises a first conduit member **102** having a conventional flanged inlet connection **104** at the forward end **106** thereof. The rearward end **108** of the conduit **102** includes a conventional blind flange assembly **112** welded thereto through which a liquefied cryogenic fluid inlet nozzle **110** passees. The nozzle **110** is comprised of a short length of pipe having an open forward end **111** and a conventional flange connection **113** at the rearward end **115** thereof. The nozzle **110** passes through and is sealingly welded to the blind flange member of flange assembly **112**. The cryogenic fluid nozzle **110** extends within the conduit **102** a short distance, and a second conduit member **116** is connected to the conduit **102**, the center line of the conduit **116** being positioned perpendicular to the center line of the conduit **102**. A conventional flange connection **118** is attached to the lower end of the conduit **116**.

In operation of the contactor apparatus **100**, a heated gas stream passes into the contactor apparatus **100** through the forward end **106** of the conduit member **102**. A stream of liquefied cryogenic fluid to be vaporized and combined with the gas stream passes through the nozzle **110** and is sprayed from the nozzle **110** within the conduit **102** in a direction countercurrent to the direction of the heated gas stream passing therethrough. The liquefied cryogenic fluid is intimately contacted by the heated gas stream within the conduit **102** causing heat to be transferred thereto which brings about the vaporization of the cryogenic fluid. The vaporized cryogenic fluid passes through the conduit **116** and out of the contactor apparatus **100**. While the contactor apparatus **100** is formed of materials resistant to cryogenic fluid temperatures, such as stainless steel or aluminum, its relatively small size and simple design makes it more economical to manufacture than other types of apparatus heretofore used.

Thus, an improved method of vaporizing and combining a liquefied cryogenic fluid stream with a gas stream is provided which may be carried out in relatively simple and inexpensive apparatus, and wherein an overall pressure reduction of the gas stream does not result. While a blower or compressor is employed to provide the driving force for causing a portion of the gas stream to be circulated through the heating circuit of the present invention, the horsepower requirements for driving the compressor or blower are inconsequential as compared to that required to raise the pressure of the entire gas stream to which the liquefied cryogenic fluid is added.

The present invention is, therefore, well adapted to carry 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 therein.

What is claimed is:

1. An improved method of combining a liquefied cryogenic fluid stream with a gas stream for transport to a point of use comprising the steps of:

dividing the gas stream into first and second portions;

elevating the pressure of the first portion of said gas stream an amount sufficient to cause the first portion to pass through a heating circuit and recombine with the second portion of said gas stream without incurring a substantial pressure drop in said gas stream;

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

injecting said stream of liquefied cryogenic fluid directly into the heated first portion of said gas stream within the heating circuit so that the liquefied cryogenic fluid is vaporized, superheated and mixed with the first portion of said gas stream;

automatically controlling the heating of the first portion of said gas stream in predetermined relationship with the temperature of the mixture of the first portion of said gas stream and vaporized cryogenic fluid so that said mixture has a desired temperature; and

combining the mixture of the first portion of said gas stream and vaporized cryogenic fluid with the second portion of said gas stream.

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 1 which is further characterized to include the steps of:

dividing said mixture of the first portion of said gas stream and vaporized cryogenic fluid into first and second portions;

combining the first portion of said mixture with the first portion of said gas stream; and

recycling the second portion of said mixture within said heating circuit.

5. The method of claim 4 wherein the gas stream is natural gas.

6. The method of claim 5 wherein the liquified cryogenic fluid is liquefied natural gas.

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U.S. Cl. X.R.

48—180 R, 180 P, 191, 196 R; 137—7, 89