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[54] **METHOD OF DILUTING LIQUEFIED GASES**

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[51] **Int. Cl.** **F25j 3/00**

[58] **Field of Search**...............48/196, 190, 196 FM, 197 FM, 48/197; 62/52; 261/126, 124, 117

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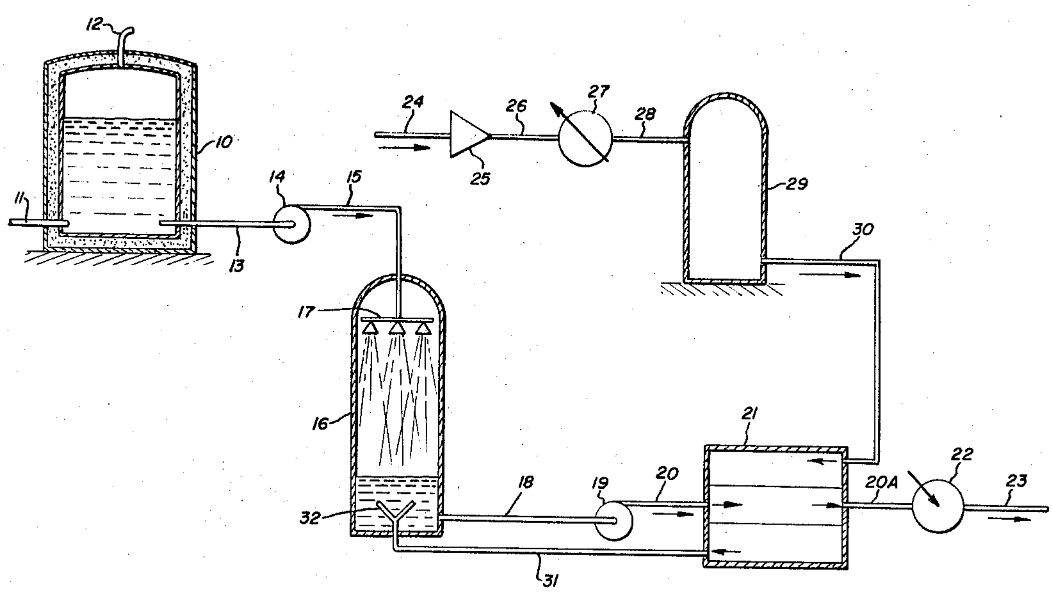
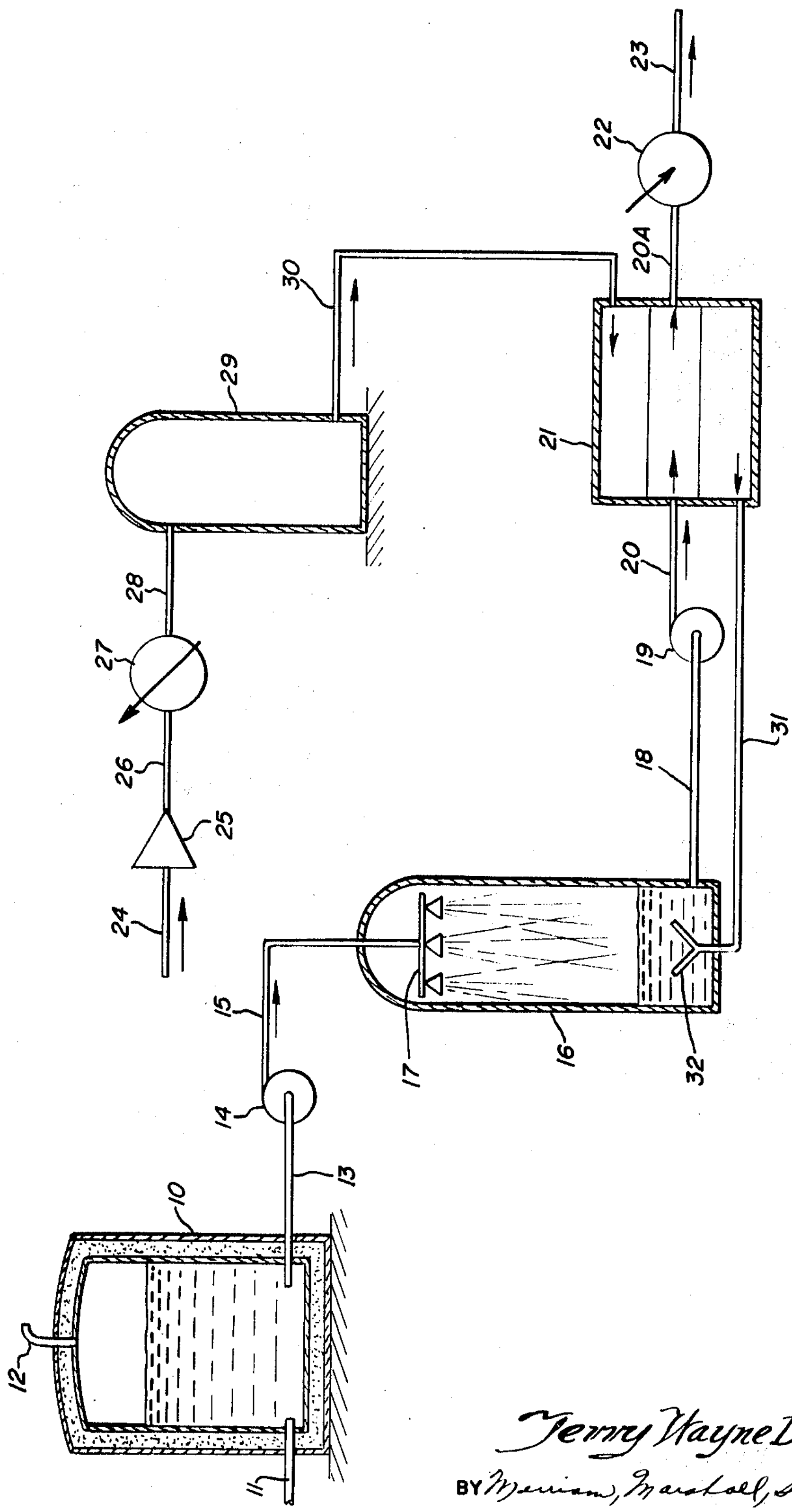
[57] **ABSTRACT**

A method in which a controlled amount of a gas of lower potential heating capacity is dissolved in an oxidizable liquefied gas to dilute the oxidizable liquefied gas and thereafter the dilute liquefied gas is vaporized. Addition of the gas of lower potential heating capacity is controlled to avoid vaporization of the oxidizable liquefied gas until after dilution. Air is used to dilute liquefied natural gas.

Apparatus having a storage tank for a liquefied oxidizable gas, a first conduit from the storage tank to a first pump for removing liquefied oxidizable gas, a second conduit from the pump to a diluting tank for delivering liquefied oxidizable gas thereto, a third conduit communicating with a second pump and the diluting tank for supplying a diluting gas to the liquefied oxidizable gas, and a fourth conduit from the diluting tank to a vaporizer for removing diluted liquefied oxidizable gas from the diluting tank and vaporizing it.

18 Claims, 1 Drawing Figure





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METHOD OF DILUTING LIQUEFIED GASES

This invention relates to the storage of liquefied oxidizable gases. More particularly, it is concerned with methods and apparatus for controlling the heating capacity of oxidizable gases vaporized after storage in the liquefied state.

There are a number of oxidizable gases which are stored in their liquid state, including natural gas (methane), ethane, propane and butane. Storage of gases in liquid form requires less space than in the vapor state. This is particularly so in the case of natural gas.

To use a liquefied oxidizable gas, it is removed from storage and vaporized. The resulting vapor is then usually mixed with an oxidizing agent, such as air, to produce heat or sometimes light, or the vapor is used in a chemical synthesis.

Because of the methods employed in liquefying an oxidizable gas, and in some cases because of the conditions used in maintaining the gas in liquid form, the heating capacity or heat of combustion or BTU content of the liquefied gas is often raised above the theoretical BTU value for the product. For example, a feed stream of natural gas to be liquefied can have a heating capacity of about 1,050 BTU per standard cubic foot, while after liquefying and maintaining the gas in the liquid form the heating capacity might be 1,100 BTU. This increased heating capacity is due to one or more of a number of changes in the gas composition which occur as a result of liquefaction and storage of the liquefied gas. For example, the heating capacity can be raised by removing water vapor and carbon dioxide from the gas prior to liquefaction. In addition, during storage the liquefied methane and dissolved nitrogen boils-off at a faster rate than the higher hydrocarbons such as ethane, propane, butane and others, thereby leading to an increased concentration of such materials in the liquefied natural gas. Since the higher hydrocarbons have higher heating capacities than methane, the liquefied gas upon subsequent vaporization has a higher BTU content than the original feed stream. It is undesirable economically, and for uniformity of supply to the customer, to feed the resulting vaporized gas of increased BTU content to a gas distribution line.

To lower the BTU content of a liquefied gas, it has been conventional practice to first vaporize it and then to inject a stream of inert gas into the revaporized stream. In the case of a natural gas distribution line, this involves pressurizing air, often to about 300 to 900 psia, and then injecting it into the vaporized gas stream. The initial and operating costs of an air compressor of adequate horsepower to pressurize the air is high for this method.

Another method involves first liquefying air and then adding the liquefied air to the liquefied natural gas. This method, while useful, also requires expensive equipment and undesirably high operating costs.

The present invention provides a novel method which involves dissolving a diluting gas in a liquefied oxidizable gas to lower its heating capacity and thereafter vaporizing the diluted liquefied oxidizable gas. The invention also provides novel apparatus for practicing the process. The diluting system of this invention requires lower initial costs and lower operating costs than the methods previously used.

According to the method of this invention, a controlled amount of a gas of lower potential heating capacity is fed to, and dissolved in, an oxidizable liquified gas to dilute the oxidizable liquefied gas and thereafter the diluted liquefied gas is vaporized. Advisably, the addition of the gas of lower potential heating capacity is controlled as to the amount added, the temperature at which added, or both, to substantially avoid vaporization of the oxidizable liquefied gas until after dilution. The process is particularly useful in using air to dilute liquefied natural gas, but it can be used to dilute other liquefied oxidizable gases with another gas of lower heating capacity and which can be oxidizable or nonoxidizable.

The apparatus provided by the invention comprises a storage tank for a liquefied oxidizable gas, a conduit from the storage tank to a walled enclosure for delivering liquefied oxidizable gas thereto, a conduit communicating with a pump and the walled enclosure for supplying a diluting gas to the liquefied oxidizable gas, and a conduit from the walled enclosure to a vaporizer for removing diluted liquefied oxidizable gas from the walled enclosure and vaporizing it.

The invention will be described further in conjunction with the attached drawing in which:

The drawing is a schematic view of apparatus useful for diluting a liquefied oxidizable gas, and specifically liquefied natural gas.

With reference to FIG. 1, liquefied natural gas is stored in insulated enclosed tank **10**. Liquefied natural gas is supplied to tank **10** by pipe **11** and vapor is removed therefrom by pipe **12**. Conduit **13** communicates with the interior of tank **10**, below the normal liquid level therein, and with pump **14** used to withdraw liquefied gas from the tank. Conduit **15** communicates with pump **14** and diluting tank **16** for spraying liquefied natural gas, by means of sprayhead **17** on the end of conduit **15**, into diluting tank or contact vessel **16**.

Diluted liquefied natural gas is removed from diluting tank **16** by conduit **18** which communicates with it and pump **19**. Pump **19** forces the diluted natural gas through conduit **20** which passes through heat exchanger **21** and by conduit **20A** into communication with vaporizer **22**. Vaporizer **22** communicates with conduit **23** which delivers the diluted vaporized natural gas to a predetermined distribution line.

Atmospheric air for diluting the liquefied natural gas is supplied by intake conduit **24** to compressor **25** from which conduit **26** conveys the compressed air to after-cooler **27**. Conduit **28** conveys the compressed air from after-cooler **27** to dryer **29** in which water and carbon dioxide are removed. The air is conveyed from dryer **29** by conduit **30**, passed through heat exchanger **21** and by conduit **31** to diluting tank **16** where it is introduced below the liquefied natural gas level therein by sparger **32**. The air dissolves in the liquefied natural gas and thereby dilutes the same.

Although not essential, even though highly advantageous, the diluting gas feed should be regulated to effect dissolution of the entire feed in the liquid being diluted. If more gas is supplied than can be dissolved, an excessive pressure will result in the diluting tank and the cost required to achieve such pressures will be greater than desired and the economic advantages of the process lowered. To facilitate dissolution of the diluting gas, it is usually advisable to precool it to a temperature which results in complete dissolution in the liquefied oxidizable gas at the lowest possible pressure. Precooling of the diluting gas is particularly suitable when relatively large amounts of diluting gas are to be dissolved, such as 10 to 15 percent of air in liquefied natural gas. However, for some liquefied gases and, for low dilutions of liquefied natural gas, precooling of the diluting gas may be unnecessary.

Also in regard to liquefied natural gas, it should generally be below −200° F. when being diluted and the diluting air should also generally be below −200° F. Generally, for diluting liquefied natural gas with air, the air can be at a temperature of about 80° F. to about −255° F. and a pressure of about 20 psia to 150 psia, and the liquefied natural gas at a temperature of about −260° F. to about −210° F. and a pressure of about 20 psia to 150 psia. Using such conditions, from about 2 to 15 percent by volume of air can be dissolved in the liquefied natural gas.

In some instances the advantages of the invention are very acceptably realized by using air cooled to within ten degrees Fahrenheit of the liquefied natural gas to be diluted and to supply the diluting air to the diluting tank at a pressure up to 150 psia.

Instead of using a diluting tank **16**, any walled enclosure can be used, including a pipe, by feeding the streams of air and liquefied gas concurrently therein.

In those cases where there is adequate back pressure supplied by other means, pump **14** may not be required. Pump **19** should, however, be employed to effect vaporization at a pressure higher than that in the contact vessel.

EXAMPLE

Liquefied natural gas in tank **10** (Fig. **1**) is at −260° F. and atmospheric pressure and has a heating value of 1,154 BTU per standard cubic foot, which is above the 1,030 BTU/SCF heating value standard of gas supplied for consumption.

To dilute the natural gas to 1,030 BTU/SCF, the ratio of diluting air to liquefied natural gas, in vapor form, must be 0.120 and the feeds are controlled to such a ratio.

The liquefied natural gas is withdrawn from tank **10** and sprayed into diluting tank **16**. The liquefied natural gas in the bottom portion of tank **16** is at about −235°F. and the pressure in the tank is about 90 psia. Air is compressed, dried and sent at 90° F. and 90 psia into heat exchanger **21** from which it emerges at −235° F. and 90 psia and is fed into the liquefied natural gas in diluting tank **16**. The diluted natural gas is removed from tank **16**, pumped to 900 psia, and sent at −235° F. and 900 psia to heat exchanger **21** from which it emerges at approximately −210° F. and 900 psia. It is then vaporized and fed at 900 psia and 40° F. to a distribution line.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom as modifications will be obvious to those skilled in the art.

WHAT IS CLAIMED IS:

1. The method of lowering the potential heating capacity of an oxidizable gas vaporized from its liquefied state which comprises dissolving a controlled amount of a gas of lower potential heating capacity in an oxidizable liquefied gas to dilute the oxidizable liquefied gas, and thereafter vaporizing the diluted oxidizable liquefied gas.

2. The method of claim **1** in which the addition of the gas of lower potential heating capacity is controlled as to the amount added, the temperature at which added, or both, to substantially avoid vaporization of the oxidizable liquefied gas until after dilution.

3. The method of claim **1** in which the oxidizable gas is liquefied natural gas and the gas of lower potential heating capacity is air.

4. The method of claim **3** in which the liquefied natural gas is at a temperature below −200° F. and the air added to the liquefied natural gas is below −200° F.

5. The method of claim **2** in which the temperature of the added diluting gas is about the same as the temperature of the liquefied oxidizable gas during the addition.

6. The method of claim **1** in which the liquefied oxidizable gas is at a pressure of not more than 150 psia during the dilution.

7. The method of lowering the potential heating capacity of liquefied natural gas which comprises:

feeding a stream of air at a temperature of about 80° F. to about −255° F. and a pressure of about 20 psia to 150 psia to liquefied natural gas at a temperature of about −260° F. to about −210° F. and a pressure of about 20 psia to 150 psia to liquefied natural gas,

the air being fed at a rate which effects substantial dilution of the air in the liquefied natural gas, and

thereafter vaporizing the diluted liquefied natural gas.

8. The method of claim **7** in which from about 2 to 15 percent by volume of air is dissolved in the liquefied natural gas.

9. The method of lowering the potential heating capacity of liquefied natural gas which comprises:

removing liquefied natural gas from a storage tank in which it is stored at about −255° F. or lower and transferring it to a diluting tank at a temperature of about −255° F. to −210° F. and a pressure of about 20 psia to 150 psia,

passing a stream of cooled air, at a pressure above the pressure in the diluting tank up to a pressure of 150 psia and at a temperature within 10° F. of the temperature of the diluted liquefied natural gas in the diluting tank, to the liquefied natural gas in the diluting tank to dissolve air therein and dilute the liquefied natural gas, and

withdrawing diluted liquefied natural gas from the diluting tank and vaporizing it.

10. The method of claim **9** in which the diluted liquefied natural gas withdrawn from the diluting tank is passed in heat exchange flow with air to supply the stream of cool air.

11. The method of claim **10** in which the stream of cool air is fed into the liquefied natural gas in the diluted tank below its surface.

12. Apparatus for diluting a liquefied oxidizable gas with another gas comprising:

a storage tank for a liquefied oxidizable gas,

a conduit from the storage tank to a walled enclosure for delivering liquefied oxidizable gas thereto,

a conduit communicating with a compressor, aftercooler and dryer and the walled enclosure for supplying a diluting gas to the liquefied oxidizable gas, and

a conduit from the walled enclosure to a vaporizer for removing diluted liquefied oxidizable gas from the walled enclosure and vaporizing it.

13. Apparatus according to claim **12** in which the conduit from the walled enclosure to the vaporizer includes a pump to aid in removing diluted liquefied gas from the walled enclosure.

14. Apparatus according to claim **12** including a heat exchanger through which the conduit from the compressor to the walled enclosure, and the conduit from the walled enclosure to the vaporizer, extend.

15. Apparatus for diluting a liquefied oxidizable gas with another gas comprising:

a storage tank for a liquefied oxidizable gas,

a first conduit from the storage tank to a first pump for removing liquefied oxidizable gas,

a second conduit from the pump to a walled enclosure for delivering liquefied oxidizable gas thereto,

a third conduit communicating with a compressor, aftercooler, and dryer and the walled enclosure for supplying a diluting gas to the liquefied oxidizable gas,

a fourth conduit from the walled enclosure to a second pump for removing diluted liquefied oxidizable gas from the walled enclosure, and

a fifth conduit from the second pump for supplying the diluted liquefied oxidizable gas to a vaporizer.

16. Apparatus according to claim **15** including a heat exchanger through which the third and fifth conduits extend.

17. Apparatus according to claim **15** in which the walled enclosure is a contact vessel, and the third and fourth conduits communicate therewith below a design liquefied oxidizable gas level of the contact vessel.

18. Apparatus according to claim **17** in which the second conduit communicates with the contact vessel above a design liquefied oxidizable gas level of the contact vessel.

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