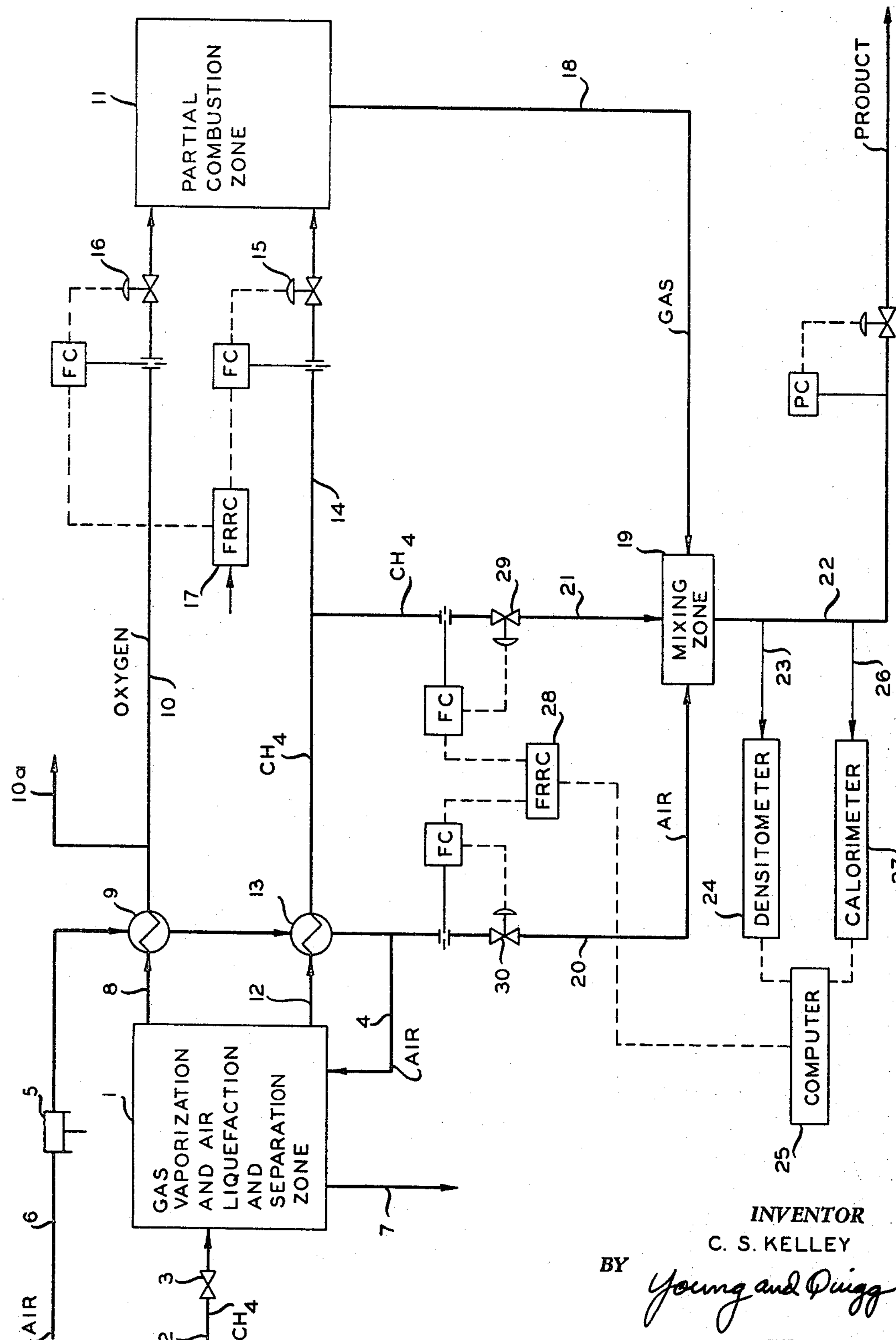
Dec. 31, 1968 C. S. KELLEY 3,419,369

MANUFACTURING TOWN GAS FROM LIQUEFIED NATURAL GAS

Filed March 19, 1965



INVENTOR
C. S. KELLEY

BY *Young and Quigg*

ATTORNEYS

3,419,369
MANUFACTURING TOWN GAS FROM LIQUEFIED NATURAL GAS

Carl S. Kelley, Bartlesville, Okla., assignor to Phillips Petroleum Company, a corporation of Delaware

Filed Mar. 19, 1965, Ser. No. 441,261
7 Claims. (Cl. 48—196)

ABSTRACT OF THE DISCLOSURE

The heating value and specific gravity of liquefied natural gas are adjusted for town gas use by vaporizing the liquefied natural gas by indirect heat exchange with air, which is partially liquefied and separated into an oxygen-rich stream; passing a portion of the vaporized natural gas and the oxygen-rich stream to a combustion zone wherein they are burned to produce an intermediate gas; and passing the intermediate gas to a mixing zone wherein controlled amounts of the remaining vaporized natural gas and air are added to produce a product having predetermined B.t.u. and specific gravity values.

This invention relates to a method and apparatus for regulating and controlling the heating value of natural gas. In one of its aspects, this invention relates to a method and apparatus for reducing the heating value of natural gas to render it suitable for household and industrial uses. In another aspect, this invention relates to a method and apparatus for reducing the heating value of natural gas to produce a gas having a desired heating value and specific gravity.

Recently there has been a sharp increase in the use of natural gas throughout the world. A considerable amount of interest has developed in the transportation of liquefied natural gases, especially methane, by barge or the like from producing fields to the place of utilization of said liquefied gas. Within the past few years, processes have been developed whereby natural gas is liquefied at or near a natural gas producing field, and then the liquefied gas is transported to its place of utilization. At the place of use, the liquefied natural gas must be revaporized before it is used as a fuel. In some localities, natural gas can be revaporized and used directly as a fuel. In other localities, the gas specifications for existing equipment therein are different from the specifications of the revaporized natural gas. This requires the revaporized natural gas to be reformed to a lower heating value and a new specific gravity before use. In localities where the revaporized natural gas is used as a supplement to or a substitute for manufactured gas, many problems arise. Natural gas has a calorific or heating value (B.t.u. content) about double that of certain manufactured gases so that it cannot be substituted for or mixed directly with such manufactured gases. Therefore, in such localities, the B.t.u. content of the revaporized natural gas must be adjusted or modified to equal that of the manufactured gas. Many processes have been proposed for adjusting the heating value of the revaporized natural gas, but these processes are undesirable because the specific gravity of the gas is also changed in the process. It is obvious, that there is need for a process and apparatus for controlling both the heating value and the specific gravity of the vaporized natural gas, before it is distributed for use.

The present invention provides a novel method of adjusting the heating value and specific gravity of a natural gas. The invention is especially useful in adjusting the heating value and specific gravity of liquefied methane at its place of use. My invention utilizes three distinct steps for regulating the heating value and specific gravity of natural gas. In the first step, the liquefied natural gas is vaporized by indirect heat exchange with air. In this vaporization step, the air is cooled to a temperature wherein it is, at least partially, liquefied and separated into an oxygen-rich stream and a nitrogen-rich stream. Controlled amounts of the vaporized natural gas and the oxygen-rich stream are then passed to a combustion zone. In the second step of my process, a portion of the vaporized natural gas and the oxygen-rich stream are burned in the combustion zone to produce an intermediate gas which is rich in hydrogen and carbon monoxide. The third step of my process includes the mixing of the intermediate gas, the remaining portion of the vaporized natural gas, and a controlled amount of air. By closely controlling the various amounts of the intermediate gas, the vaporized methane and the air, it is possible to produce a finished gaseous product having a heating value and a specific gravity that is very near that of manufactured town gas.

Therefore, an object of this invention is to provide a method and apparatus for reducing the heating value of liquefied natural gas. Another important object of this invention is to provide a method and apparatus for producing a gaseous product having a controlled heating value and a controlled specific gravity.

Other objects, advantages and aspects of this invention will be evident to those skilled in the art upon examination of the following description, drawing, and claims.

The features and method of operation of my invention can best be understood by reference to the drawing. The drawing is a diagrammatic representation of one form of equipment which may be used in the process of the invention.

In the drawing, liquified natural gas is supplied to gas vaporization and air liquefaction-separation zone **1** through conduit **2**. The flow of liquefied gas through conduit **2** is easily controlled by means of flow control valve **3**. In gas vaporization and liquefaction-separation zone **1**, the liquefied natural gas is vaporized by indirect heat exchange with air which is supplied through conduit **4**. Since large volumes of high pressure air are required in the process, air compressor **5** is utilized to gather air from the atmosphere through line **6** and compress it. Since the liquefied natural gas is at an extremely low temperature, it cools the high pressure air stream in gas vaporization and air liquefaction zone **1** to a point where the air is partially liquefied and separated into two streams. One stream contains a major amount of oxygen and the other stream is predominantly nitrogen. Air liquefaction and separation processes are well known in the art and are not explained in detail here. The stream rich in nitrogen is removed through conduit **7**. This nitrogen-rich stream can either be recovered for chemical usage, recovered for refrigerant value, vented to the atmosphere, or in some cases it may be bottled and sold for industrial uses. The oxygen-rich stream is withdrawn from gas vaporization and air liquefaction zone **1** through conduit **8**. The very cold oxygen-rich stream is passed through heat exchanger **9** in indirect heat exchange with the compressed air stream from compressor **5**. Since the compressed air stream from compressor **5** is at an elevated temperature, the oxygen-rich stream is heated to a point where it is revaporized. A portion of the oxygen-rich stream then flows through conduit **10** to partial combustion zone **11**. The remaining portion of oxygen-rich stream is withdrawn from the system through conduit **10***a*. The remaining portion of the oxygen-rich stream can either be recovered for chemical use, recovered for refrigerant value, vented to the atmosphere, or bottled and sold for industrial uses. Vaporized natural gas is withdrawn from gas vaporization and air liquefaction zone **1** through conduit **12**. The vaporized natural gas is also passed to heat exchanger **13** wherein it additionally, in indirect heat exchange, cools the compressed air stream from air compressor **5**. A portion of the vaporized natural gas flows through conduit **14** to partial combustion zone **11**. The relative amounts of natural gas and oxygen flowing to partial combustion zone **11** are regulated by means of control valves **15** and **16**, respectively. By simple stoichiometric calculations the ratio of natural gas to oxygen for partial combustion can be conveniently calculated. After this ratio is determined, flow ratio recorder controller **17** can be used to maintain the proper ratio. In partial combustion zone **11**, the natural gas is partially burned to produce an intermediate gas which is rich in oxygen and carbon monoxide. Such processes are well known in the art and have been used for many years in the manufacture of town gas. One such process is described in Petroleum Refiner, vol. 38 (1959), No. 11, p. 294. The intermediate gas from partial combustion zone **11** is withdrawn through conduit **18**. The intermediate gas is then passed to mixing zone **19**. In mixing zone **19**, the intermediate gas is mixed with controlled amounts of air which are added through conduit **20**. The air stream in conduit **20** can be a portion of the compressed air stream from air compressor **5**. The remaining portion of the vaporized natural gas from conduit **12** is also added to mixing zone **19** through conduit **21**. The exact amounts of the intermediate gas, vaporized natural gas and air that are added to mixing zone **19** is very critical. By carefully controlling the various amounts of intermediate gas, vaporized natural gas and air that are added to the mixing zone **19**, it is possible to produce a final gas having a desired heating value and specific gravity. The determination of the proper amounts of the various components to be added to mixing zone **19** is accomplished by continuously sampling a small portion of the mixed gas that is withdrawn from mixing zone **19** through conduit **22**. A small amount of the mixed gas is withdrawn through conduit **23** and passed to densitometer **24**. In densitometer **24**, the density or specific gravity is determined and a signal proportional to the specific gravity is passed to computer **25**. The heating value or B.t.u. content of the mixed gas from mixing zone **19** is determined by withdrawing a small portion of the gas through conduit **26** and passing it to a calorimeter **27**. A signal proportional to the B.t.u. content of the gas is passed from calorimeter **27** to computer **25**. Computer **25** effectively controls the amounts of air and vaporized natural gas that are added to mixing zone **19**. Since the various gaseous streams entering mixing zone **19** have different specific gravities or densities, it is easily seen that computer **25** serves to control the specific gravity of the final gas product in conduit **22**. Since the intermediate gas entering mixture zone **19** through conduit **18** is very rich in hydrogen, it is less dense than the vaporized natural gas or the final gas product. Similarly, air entering mixing zone **19** through conduit **20** is more dense than the final gas product in conduit **22**. When the density of the gas in conduit **22** is too great, computer **25** sends a signal to flow ratio recorder controller **28** that will decrease the amount of air flowing through conduit **20** by means of flow control valve **30**. Conversely, when the density of the gas in conduit **22** decreases below the predetermined limit, computer **25** serves to add more air by means of flow ratio recorder controller **28** and flow control valve **30**. Also, it is easily seen that when the B.t.u. value of the gas in conduit **22** falls below the desired level, computer **25** sends a signal to flow ratio recorder controller **28** which resets flow control valve **29** and allows more vaporized natural gas (which gas itself has a specific gravity in the range desired for the final product) to enter mixing zone **19**. Since the vaporized natural gas has a higher B.t.u. content than the intermediate gas entering the mixing zone **19**, the B.t.u. content of the gas will be increased. Conversely, if the B.t.u. content of the gas rises above the predetermined limits, computer **25** sends a signal to flow ratio recorder controller **28** which resets flow control valve **29**, thus decreasing the amount of vaporized natural gas entering mixing zone **19**. Thus, it is seen that the combination of densitometer **24**, computer **25** and calorimeter **27** furnish a unique method of controlling both the specific gravity and the B.t.u. content of the final gas product. By this process, it is possible to adjust the heating value and the specific gravity of the final product to maintain the desired values for these properties. Various components that can be used in the apparatus described above are well known in the art and have not been described in detail here. It is understood that various heat exchangers, gas compressors, etc., not shown in the drawing, may be necessary for actual operation of my invention. Gas flowing through conduit **22** can be added directly to gas distribution mains or it can be passed to a suitable storage vessel. Thus, it is evident, that by utilizing this process it is possible to operate in a continuous process to produce a gas product having a predetermined heating value and a predetermined specific gravity. The following example is included to show various operating conditions and stream compositions of the process. Also, two or more units of the invention can be used in parallel.

EXAMPLE

The apparatus shown in the drawing is used to produce a town gas having a gross heating value of 500 B.t.u. per standard cubic foot with a gas specific gravity of 0.55 (air is 1.00). Liquid methane is supplied through conduit **2** at a temperature of −250° F. Partial combustion zone **11** is operated at a temperature of 2100° F. and at a pressure of 450 p.s.i.a. The catalyst utilized in the partial combustion zone is granular magnesite with a 3 percent by weight nickel content. The resulting gas product is passed through a desiccant and then is added directly to the gas distribution lines or to a suitable gas storage vessel. The following table illustrates various stream compositions, B.t.u. content, and specific gravity measurements that are found in the process of this invention.

TABLE

Component	Stream Number (Values given in s.c.f./hr.)							
	2	10	12	14	18	20	21	22
Methane	1,056		1,056	450	1		606	607
Hydrogen					595			595
Oxygen		280				50		50
Nitrogen		4			4	188		192
Carbon Monoxide					380			380
Carbon Dioxide					20			20
Total	1,056	284	1,056	450	1,000	238	606	1,844
B.t.u./s.c.f.	1,000		1,000	1,000	316		1,000	500
Gas Specific Gravity	0.554	1.000	0.554	0.554	0.443	1.000	0.554	0.55

B.t.u.=British thermal unit; s.c.f.=standard cubic feet.

As will be evident to those skilled in the art, many variations and modifications of the invention can be practiced in view of the foregoing disclosure. Such variations and modifications are believed to come within the spirit and scope of the invention.

I claim:

1. Method for reducing the heating value of a liquefied natural gas comprising:

(a) vaporizing said liquefied natural gas in a vaporizing zone by passing air in indirect heat exchange therewith, said air being liquefied;

(b) separating an oxygen-rich stream from said liquefied air;
(c) removing a vaporized natural gas stream from said vaporizing zone;
(d) passing a portion of said vaporized natural gas stream and at least a portion of said oxygen-rich stream to a combustion zone;
(e) partially combusting the vaporized natural gas in said combustion zone to produce hydrogen and carbon monoxide as an intermediate gas product;
(f) passing said intermediate gas product from said combustion zone to a mixing zone;
(g) passing air and at least a portion of the remainder of said vaporized natural gas stream of step (c) to said mixing zone, the amount of air and said vaporized natural gas added to said mixing zone being sufficient to produce a gaseous mixture having a predetermined specific gravity and a predetermined heating value lower than said liquefied natural gas; and
(h) recovering said gaseous mixture.

2. The method according to claim **1** further comprising cooling the air before introduction into said vaporizing zone by passing in indirect heat exchange relationship with said oxygen-rich stream and said vaporized natural gas stream.

3. The method according to claim **1** wherein sufficient air and vaporized natural gas are added to said mixing zone to produce a gaseous mixture having a specific gravity of 0.55 and a gross heating value of 500 B.t.u. per standard cubic foot.

4. The method according to claim **1** further comprising:
(a) measuring the specific gravity of said gaseous mixture and producing a first signal representative thereof;
(b) controlling the addition of air to said mixing zone in response to said first signal so that, as the specific gravity of said gaseous mixture increases above a predetermined level, the amount of air added to said mixing zone is decreased and, as the specific gravity of said gaseous mixture decreases below a predetermined level, the amount of air added to said mixing zone is increased;
(c) measuring the B.t.u. value of said gaseous mixture and producing a second signal representative thereof; and
(d) controlling the addition of vaporized natural gas to said mixing zone in response to said second signal so that, as the B.t.u. value of said gaseous mixture increases above a predetermined level, the amount of vaporized natural gas added to said mixing zone is decreased and, as the B.t.u. value of gaseous mixture decreases below a predetermined level, the amount of vaporized natural gas added to said mixing zone is increased.

5. A system for reducing the heating value of liquefied natural gas and maintaining the thus-treated product at a predetermined specific gravity comprising, in combination:
(a) means for vaporizing said liquefied natural gas by passing air in indirect heat exchange relationship therewith so that said air is at least partially liquefied;

(b) means for separating an oxygen-rich stream from said liquefied air;
(c) a combustion means for partially combusting vaporized natural gas in oxygen to produce an intermediate gas product containing hydrogen and carbon monoxide;
(d) first conduit means for passing at least a portion of said oxygen-rich stream to said combustion means;
(e) second conduit means for passing a portion of the vaporized natural gas from said vaporizing means to said combustion means;
(f) a mixing means;
(g) third conduit means for passing said intermediate gas product from said combustion means to said mixing means;
(h) fourth conduit means having a first control means disposed therein for introducing controlled amounts of air into said mixing means;
(i) fifth conduit means having a second control means disposed therein for introducing controlled amounts of a portion of said vaporized gas from said vaporizing means to said mixing means;
(j) sixth conduit means for withdrawing a gaseous mixture from said mixing means;
(k) means for measuring the specific gravity of said gaseous mixture passing through said sixth conduit means and producing a first signal representative thereof;
(l) means for manipulating said first control means in response to said first signal so that the amount of air added to said mixing means is sufficient to maintain the specific gravity of said gaseous mixture at a predetermined level;
(m) means for measuring the B.t.u. level of said gaseous mixture passing through said sixth conduit means and producing a second signal representative thereof; and
(n) means for manipulating said second control means in response to said second signal so that the amount of vaporized natural gas added to said mixing means is sufficient to maintain the B.t.u. value of said gaseous mixture in said sixth conduit at a predetermined level.

6. A system according to claim **5** wherein said means for measuring specific gravity is a densitometer.

7. A system according to claim **5** wherein said means for measuring B.t.u. is a calorimeter.

References Cited

UNITED STATES PATENTS

2,547,970	4/1951	Phillips et al.	
2,557,171	6/1951	Bodle et al.	48—196 XR
3,057,706	10/1962	Marshall et al.	48—196
3,241,933	3/1966	Ploum et al.	48—196
3,285,719	11/1966	Bodle et al.	48—196 XR

MORRIS O. WOLK, *Primary Examiner.*

R. E. SERWIN, *Assistant Examiner.*

U.S. Cl. X.R.

48—190