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METHOD OF PREPARING FUEL GAS INTERCHANGEABLE WITH NATURAL GAS

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Fig. 1

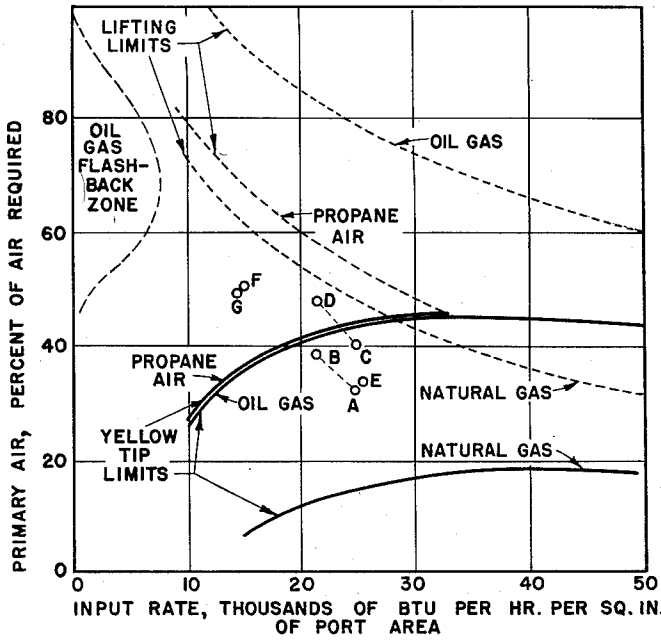
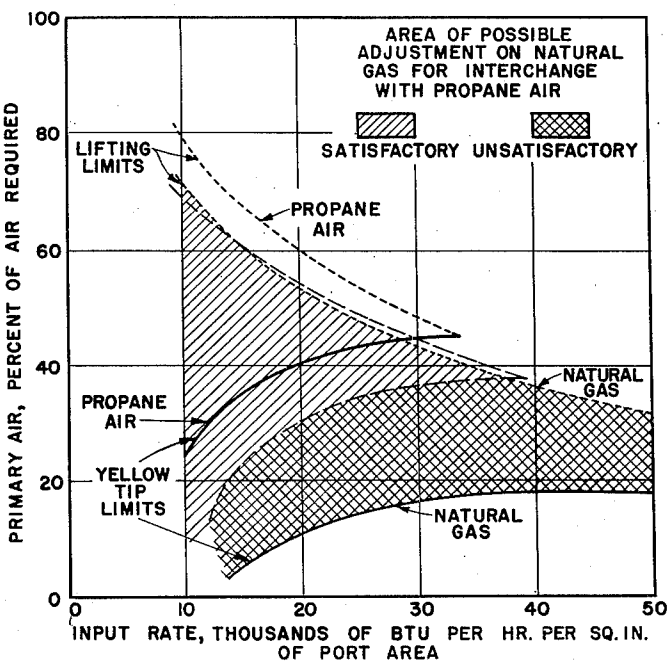


Fig. 2



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METHOD OF PREPARING FUEL GAS INTERCHANGEABLE WITH NATURAL GAS

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1 Claim. (Cl. 48—196)

This invention relates to a gas completely interchangeable with natural gas and to a method of preparing such a gas.

Natural gas comprises upwardly of 85% of paraffins having an average carbon number ranging from 1.0 to 1.3. The remainder is essentially nitrogen and/or other incombustible material. Natural gas is free from hydrogen and unsaturated hydrocarbons. The heating value of natural gas ranges from about 970 to 1100 or in some rare instances as much as 1200 B. t. u./s. c. f. The specific gravity (air=1.000) ranges between 0.6 and 0.7.

Reference is made to Fig. 1 of the drawing for a discussion of what is meant by the "interchangeability" of a fuel gas with natural gas. Fig. 1 shows graphically the effects of the gas input rate in the operation of a gas burner (in terms of thousands of B. t. u. per hour per sq. in. of port area) and of rate of primary air input into the gas burner (in terms of per cent of amount of air required for total combustion of the gas being burned) upon the so-called "characteristic flame limit curves" of a typical natural gas (having a heating value of 1,000 B. t. u./s. c. f. and a specific gravity of 0.64), of a typical conventional oil gas (having a heating value of 1070 B. t. u./s. c. f., a specific gravity of 0.72 and containing about 20% hydrogen, about 24% olefins, and about 35% methane) and of a typical conventional propane-air mixture (having a heating value of 1200 B. t. u./s. c. f. and a specific gravity of 1.26).

As shown by the broken line curve in Fig. 1, "flash back" of an oil gas flame will occur at certain relatively low gas input rates at certain relatively high rates of primary aeration.

As shown by the dotted lines, there is (for each of the three types of fuel gases) a maximum amount of primary air which may be supplied to the burner without the occurrence of lifting flames. If primary aeration is increased beyond this maximum, lifting flames will result. As shown by the full lines, there is also a minimum amount of primary air which must be supplied to the burner to prevent yellow tipping of the flames. A satisfactory burner adjustment with respect to air shutter setting may obviously be represented, for any one fuel gas, by any point between these two limit curves.

The interchangeability of any two fuel gases will depend upon the adjustment of the particular burner in which the gases are burned. As will be shown hereinbelow, it is entirely possible to have two different fuel gases completely interchangeable at one burner adjustment while at another burner adjustment, only a small amount of one gas (the supplemental gas) may be added to the other gas (the base gas).

To illustrate this fact, we assume the first case of a given burner adjusted with respect to fuel gas input rate and primary aeration for burning natural gas, the exact adjustment being represented in Fig. 1 by the point A. If a typical propane-air mixture is introduced into the line leading to the burner (in place of natural gas), without any change in the setting of the air shutter in the gas

orifice, the burner adjustment is then represented by the point B in Fig. 1, because of the differences in heating value and specific gravity as between the natural gas and the propane-air mixture. The point B falling below the curve defining the yellow tip limit for the propane-air mixture, this mixture will burn with yellow tips at this particular burner adjustment, which is unsatisfactory. In other words, at this particular setting of the gas burner the natural gas and the propane-air mixture are not completely interchangeable. However, a limited amount of the propane-air mixture could be added to the natural gas without causing an occurrence of yellow tips at this particular burner setting. At this burner setting, the propane-air mixture is interchangeable with the natural gas to a limited extent only.

If we assume, as a second case, that the same gas burner is originally adjusted for burning natural gas with a setting represented in Fig. 1 at the point C (which is a "harder" setting than the point A, as explained hereinbelow), then the setting on the burner after substituting the propane-air mixture for the natural gas would be represented by the point D. Since the point D lies above the curve defining the yellow tip limit for the propane-air mixture but below the curve defining the lifting limit for the propane-air mixture, this mixture will then burn satisfactorily. In other words, at this second setting of the burner, the two gases are completely interchangeable, although at this setting the natural gas burns with a "hard" flame.

If we assume a third case where the burner is adjusted for burning natural gas at the setting indicated in Fig. 1 at the point A (as in the first case), but a typical oil gas is substituted for the natural gas, then the resulting setting of the burner is indicated in Fig. 1 at the point E, which falls below the curve indicated at the yellow tip limit of the oil gas. This setting is unsatisfactory for burning oil gas. In other words, the gases are not completely interchangeable at this burner setting, although a small amount of the oil gas could be added to the natural gas.

If we assume a fourth case where the burner is adjusted for burning natural gas at the setting indicated in Fig. 1 at the point F, then substituting oil gas for the natural gas would cause the burner setting to be indicated at the point G, which lies between the curves for oil gas defining its lifting limits and its yellow tip limits. Therefore, the oil gas would burn satisfactorily. In other words, at this burner setting the two gases are completely interchangeable.

It is also evident from the curves of Fig. 1 that there are instances or conditions in which partial or complete interchangeability of two fuel gases in a given burner cannot be obtained. For instance, the propane-air mixture would always burn with yellow tips when a specific burner is adjusted on natural gas at an input rate greater than about 35,000 B. t. u. per hour per sq. in. of port area. Or when the burner is adjusted on oil gas at an input rate of about 35,000 B. t. u. per hour per sq. in. of port area it would always have lifting flames when operated on natural gas. Interchangeability could only be effected by either redrilling the burner ports or else reducing the actual total input rate.

The interchangeability of the same natural gas and the same propane-air mixture (as discussed in connection with Fig. 1) is illustrated graphically and in further detail in Fig. 2 where again the effects of the fuel gas input rate and of the primary aeration upon the flame characteristics of the fuel gases are shown by means of curves. As in Fig. 1, the dotted lines indicate the lifting limits and the full lines, the yellow tip limits. Further (as explained hereinbelow), areas indicating possible satisfactory adjustment on natural gas permitting com-

plete interchanging with the propane-air mixture are hatched, while areas indicated possible satisfactory adjustment on natural gas not permitting complete interchanging with the propane-air mixture are cross-hatched.

When the burner is adjusted on one fuel gas, and thereafter the other fuel gas is introduced into the burner, the representation of the same actual burner setting is represented on Figs. 1 and 2 by a different point, in accordance with the relative heating values and specific gravities of the two fuel gases. Thus, all the possible satisfactory actual settings of the burner of the propane-air mixture are represented by the area enclosed within the two curves representing the lifting and yellow tip limits for the propane-air mixture. These same actual settings are represented in Fig. 1, when natural gas is burned, by the area enclosed within the two broken lines. This last-mentioned area lies almost completely within the lifting and yellow tip limits of the natural gas. Thus, except for a very limited number of actual burning settings, natural gas may satisfactorily and completely be substituted for the propane-air mixture.

Further, any burner operating on natural gas at an adjustment point located in the hatched area will perform satisfactorily when the propane-air gas is introduced into the burner. Thus, the hatched area represents all the actual burner settings at which the two fuel gases may be freely substituted each for the other.

It will be noted that the actual burner settings on natural gas (and satisfactory for burning natural gas) falling within the cross-hatched area of Fig. 2 are not satisfactory for burning a propane-air mixture.

Thus, natural gas may be substituted practically at will for a propane-air mixture without any change in the actual burner setting but a propane-air mixture is not necessarily or always completely interchangeable with natural gas without adjustment of the actual burner setting.

A diagram of a general type shown in Fig. 2 can also be constructed to show the limits for interchanging conventional oil gas and natural gas.

The limits set by the curves of Figs. 1 and 2 define only the burner settings at which the fuel gases will burn without flash back, lifting or yellow tips. Such burning has hereinabove been described as being "satisfactory." For the purposes of the present discussion, this term may be considered as synonymous with "operative." Other flame characteristics, which may vary without occurrence of flash back, lifting or yellow tips (for instance, flame length) are not indicated by the data graphically presented in Figs. 1 and 2. These other flame characteristics (along with others discussed hereinabove) are set out in the American Gas Association code for describing flame characteristics which is given as follows:

Code No.	Flame Description
+5	Flames lifting from ports with no flame on 25% or more of the ports.
+4	Flames tend to lift from ports, but become stable after a short period of operation.
+3	Short inner cones; flames may be noisy.
+2	Inner cones distinct and pointed.
+1	Inner cones and tips distinct.
0	Inner cones rounded; soft tips.
−1	Inner cones visible; very soft tips.
−2	Faint inner cones.
−3	Inner cones broken at top; lazy wavering flames.
−4	Slight yellow streaming in the outer mantles or yellow fringes on the tops of the inner cones; flames deposit no soot on impingement.
−5	Distinct yellow in outer mantles or large volumes of luminous yellow tips on inner cones; flames deposit soot on impingement.

It will be apparent that the "satisfactory" limits shown graphically in Figs. 1 and 2 indicate burner settings yielding flames ranging from +3 to −3 on the above scale and include relatively hard (+3) and relatively soft (−3) flames that (although operative in the broad sense of this word) are not desirable for ordinary commercial or domestic heating.

For the purposes of the present application, applicants introduce the novel term "absolutely interchangeable." This novel term designates that, given two fuel gases, these two fuel gases are completely interchangeable, each for the other, at any actual burner setting at which either fuel gas can be burned to give a flame within the range of from +2 to −2 on the American Gas Association code, the flame then obtained by substituting either gas for the other gas still falling within the range of from +2 to −2 on the American Gas Association code.

At the present time, the gas industry is not familiar with any gas differing substantially in composition from natural gas and yet absolutely interchangeable therewith, nor with any methods for making such a gas.

In the last 20 years, the use of natural gas by public utility companies has increased tremendously, to the extent where in 1949 some twenty or more per cent of the total energy consumed in the United States was furnished by natural gas. This natural gas has been made available at the various localities where it is burned by transmission through pipelines. As the use of natural gas has increased, the problem of meeting the seasonal peak load demands has become more and more difficult. This problem is brought about by the tremendous demand for gas on the peak load days, usually the coldest winter days, when several times the average daily sendout is required, and has been made particularly acute by a disproportionate rate of growth of gas sales for house and other space heating. It should be noted that long distance natural gas transmission lines can be built economically only to handle a steady high load. Up to the present time, there has been no really satisfactory solution to the peak load problem, in view of the fact that no gas absolutely interchangeable with natural gas has been available. Utility companies have, therefore, been forced to blend their sendout of natural gas with other gases only partially interchangeable with natural gas, with resultant unsatisfactory burning characteristics of the resultant mixture if excessive amounts of such other gases have been incorporated with the mixture. Further, even such only partially interchangeable gases have been produced only at excessive costs, either due to heavy capital investments for manufacturing apparatus used only to meet peak demands, or due to high costs of the gas manufacture apart from the required capital investment for apparatus, or due to a combination of these two factors.

It is, therefore, an important object of the present invention to provide a fuel gas absolutely interchangeable with natural gas and, therefore, particularly well adapted for meeting peak load demands for natural gas.

Another object is to provide a simple relatively inexpensive method for making a fuel gas absolutely interchangeable with natural gas capable of being carried out in an apparatus of relatively low cost.

Other and further objects and features of the present invention will become apparent from the following description and appended claim.

We have provided a gas absolutely interchangeable with natural gas and having the following characteristics. The heating value of the gas in question (expressed as B. t. u./s. c. f.) when divided by the square root of the specific gravity of the gas (air=1.000) falls within a range obtained by dividing the heating values of the natural gases (identically expressed) by the square roots of the specific gravities (air=1.000) of the natural gases. Subject to the above qualification, our novel gas has a composition within a range given as follows. The content of paraffins ranges from 60 to 80%, and the average carbon number of these paraffins ranges from 1.0 to 1.3. The gas is essentially free from aromatics. The remainder of the gas consists essentially of from ½ to ⅔ hydrogen and from ⅔ to ⅓ of unsaturated gaseous hydrocarbons, principally ethylene.

We have also provided a method for making not only the above gas but also other gases absolutely interchange-

able with natural gas. The starting materials for this method are propane, butane, and/or natural gasoline. Using conventional apparatus, the starting material is cracked thermally under critically important conditions given as follows. The temperature ranges from about 1460° to 1540° F. The pressure ranges from 3 to 4 atmospheres. The residence time ranges from 3 to 5 seconds and is preferably from 4 to 5 seconds, particularly at a pressure of 3 atmospheres. The oil gas produced by thermal cracking under these critically important conditions from the materials above indicated is scrubbed with a suitable petroleum oil to remove its content of aromatics. The residual gas then obtained is absolutely interchangeable with natural gas, either as obtained or, when to be used as a substitute for natural gas containing relatively large amounts of incombustible material, in admixture with small amounts of incombustible gases such as air, nitrogen or combustion gases. Further, under the indicated conditions, cracking of the above-noted starting materials can be carried out continuously (except for short and regularly scheduled interruptions for removal of carbon deposits). The amount of carbon deposited under the indicated conditions is less than 2½% by weight of the material being cracked.

By way of illustrative examples, we describe hereinbelow specific methods of cracking butane, propane, and natural gasoline which we have carried out. According to these methods, the starting material (in vapor form) was passed through a heated stainless steel tube. The resulting oil gas was passed through a heavy tar separator in which the tar condensed from the gas at the outlet of the cracking tube was collected. Light tar was next condensed from the gas in an adjacent water-cooled condenser. Any remaining tar fog was next removed with an electrostatic precipitator. The gas was next passed through another water-cooled condenser, through a box packed with iron oxide sponge, through a diaphragm-type pressure regulator operative to maintain super-atmospheric pressure within the cracking tube and through a light oil scrubber. The amount of gas generated was then determined and the heating value, specific gravity, composition and burning characteristics of the gas were ascertained. The operating data and the results are tabulated as follows:

	Starting Material		
	Butane	Propane	Natural Gasoline
Cracking Temperature, ° F	1500	1500	1500
Pressure, atm. abs	3.19	3.05	3.11
Residence Time, sec	4.62	4.23	4.91
Oil Feed, lb./hr	5.25	4.55	5.62
Make Gas, s. c. f./hr	75.9	79.4	69.6
Liquid Products, wt. percent	25.3	22.2	30.6
Carbon Deposit, wt. percent	2.30	0.55	2.47
Make Gas Heating Value, B. t. u./s. c. f.	1072	1048	1064
Specific Gravity	0.627	0.612	0.620
Composition, mol. percent:			
Paraffins	61.8	63.8	61.9
Olefins	16.3	17.3	16.0
Aromatics	0.9	0.7	0.7
Hydrogen	20.9	18.1	19.8
Other	0.1	0.1	1.6
Average C Number of Paraffins	1.10	1.08	1.10

The fuel gases thus produced were found to be absolutely interchangeable with natural gas.

Many details of composition and procedure may be varied without departing from the principles of the invention, and it is, therefore, not our purpose to limit the patent granted on this invention otherwise than necessitated by the scope of the appended claim.

We claim:

A method of preparing a gas absolutely interchangeable with natural gas which comprises providing in vapor form a material selected from the class consisting of butane, propane, natural gasoline and mixtures thereof, passing said vapor through a tube at a temperature of from 1460° to 1540° F., at a pressure of from 3 to 4 atmospheres absolute and a residence time of from 3 to 5 seconds, to crack said vapor thermally with formation of products including a gaseous fraction containing aromatics and a fraction condensable by cooling, cooling said products to condense said last-mentioned fraction, and scrubbing said gaseous fraction to remove at least a major portion of said aromatics.

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