QUALITY REQUIREMENTS FOR SNG

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Substitute natural gas (SNG) produced from liquid or solid fuels will become a major factor in supplementing our natural gas supply during this decade. To date, six plants to produce 1.6 billion cubic feet per day of SNG from liquid fuels and two plants to produce 500 million cubic feet per day of SNG from coal have been announced. Although this half a trillion cubic feet per year of SNG is minuscule in relation to the 23 trillion cubic feet of natural gas distributed last year, some consideration must be given to the quality requirements if this SNG is to be satisfactory to the domestic gas industry.

To be a satisfactory supplement, SNG must be completely interchangeable with natural gas. One way to assure complete interchangeability is to synthesize a product having the same composition as natural gas. In nearly all cases this means synthesizing a product consisting of over 85% methane.

In the processes under consideration for producing SNG from liquid or solid fuels, the product gas must undergo a catalytic methanation step to achieve methane contents approaching 85% methane. This operation adds cost to the SNG, and it may not be to the best interest of the consumer or the gas industry to synthesize a high methane SNG if other compositions are satisfactory. This paper will show that a wide range of gas compositions can be satisfactorily substituted for natural gas.

In 1965, Grumer and Harris[1] performed a study of the interchangeability of methane-hydrogen mixtures with natural gas. They found that complete identity between the substitute and natural product is not necessary. Methane-hydrogen mixtures having between 25 to 37% hydrogen can be tolerated in the sendout gas.

The American Gas Association[2] has developed empirical indices to compute the interchangeability of various gas mixtures used for peaking. This investigation studied the effect of supplemental gases such as coke oven gas, producer gas, carburetted water gas,and hydrocarbon-air mixtures, in admixture with natural gas on combustion characteristics of appliances.

In order to properly assess the interchangeability factors, one must consider the use of natural gas and the effect of compositional change on the customers involved. Table I shows the gas demand in 1970 as to class of service. Nearly 21-1/2 trillion cubic feet of natural gas were distributed in 1970. Thirty-two percent was sold to residential and commercial customers. All of these seven trillion cubic feet were used for energy in the form of heat. The industrial category consumed 27.7% of the total in various applications: as heat, controlled atmosphere, chemical feedstock, and others. The electric utility consumed 18.3% of the gas as fuel in power generation. The interruptible category of three trillion cubic feet was probably used as heat because it is an economical form of heat for the large volume customer. The other category includes company uses, transmission mainline fuel, and other sales not otherwise classified. Over two thirds of all the gas distributed is used in combustion.

This is not the whole story. Table II shows the gas consumers broken down into type of customer. The residential and commercial customers constitute 99-1/2% of the total number of customers, leaving only 0.6%. These 249,000 customers, including industrial, electric utility, and interruptibles, consume over 60% of the natural gas. In terms of sheer numbers, over 41 million customers use natural gas as fuel and if the interchangeability requirements are designed to satisfy these users, the balance can be handled on an individual basis if needed. Therefore, this paper will address itself to quality requirements of SNG when used as a heat source in combustion devices used in residential and most commercial and industrial applications.

The properties of SNG must be such that there is minimum effect on performance of gas appliances when it is substituted for natural gas. This means that the SNG should give similar heat inputs, good flame stability, and complete combustion without adjustment of the appliance. Table III shows the interchangeability factors used for assessing substitutibility.

In a gas appliance having a fixed orifice, the flow of gaseous energy or heat input through the orifice at constant pressure varies directly as the heating value, h, of the gas and inversely at the square root of the specific gravity, d. This relationship is referred to as the Wobbe number. Empirically, if the Wobbe number of the two gases is within 10%, the gases are interchangeable, providing othe factors do not adversely affect flame characteristics. The Wobbe number is useful for a cursory examination of the interchangeability of two gases because of its simplicity. Alone, the Wobbe number does not give a definitive answer to interchangeability. The British Gas Council[5] has developed a combustion diagram which relates the Wobbe number to a flame speed factor. In this relationship, the Wobbe number must not fall below 1202 to ensure satisfactory heat input to an appliance. For SNG with a heating value of 1000 BTU/CF, the Wobbe number should be in the range of 1335 ± 5% and a flame speed as low as possible.

To assess the flame characteristics of SNG burned in an appliance adjusted for burning natural gas, the interchangeability indices developed by the A.G.A. Labo tories[2] are believed to be more useful because they take into account the composition of the substitute gas.

Three empirical indices were developed to compare flame characteristics. These are, I_L, the lifting index, I_F, the flashback index, and I_Y, the yellow-tip index. These indices, valid for gases having a heating value greater than 800 BTU/C will predict if the substitute gas will cause flame lifting, yellow-tipping, or flas back. I will not discuss the parameters entering into each index; these are discuss in the bulletin. In Table III it will suffice to show the range of values desired.

In addition to these computations on SNG substitutibility, actual applianc combustion tests were made to confirm the results. A wide variety of burners was used to ensure that most combustion appliances were covered.

GAS COMPOSITIONS CONSIDERED AND TESTED

Five different SNG gas compositions were considered for their interchangeability with natural gas - four compositions from naphtha gasification and one from coal gasification. The names of the processes for SNG production are identified in this paper to depict actual situations and to facilitate understanding and do not imply process endorsement by the author.

1. SNG from Single-Stage Gasification

The first gas composition for interchangeability considerations was that product gas from a single-state catalytic gasification of naphtha with steam. Figur 1 shows the product composition from the British Gas Council process after CO_2 remov The gas composition consists of 80% methane with 17.4% hydrogen. It has a heating value of 869 BTU/CF and a specific gravity of 0.493. This gas is considered for interchange with a natural gas of 1030 BTU/CF heating value and 0.587 gravity.

The Wobbe number of the SNG is 1238, and that of the natural gas is 1343. The ratio of the Wobbe number, W_n/W_s, is 1.087; i.e., the Wobbe numbers are within 8% of each other. This means that the heat input rate through a fixed orifice is within acceptable limits and the gases are interchangeable, providing other factors do not adversely affect flame characteristics.

The interchangeability indices are well within the acceptable limits for lifting, flashback, and yellow-tipping.

Combustion tests show this particular gas to be completely interchangeable with the natural gas.

2. Above SNG Enriched with Ethane

Since some utilities may have to meet certain heating value requirements, this SNG gas was enriched with ethane to 1030 BTU/CF. Figure 2 shows the pertinent data. The heating value was adjusted with ethane to the same as the natural gas, 1030 BTU/CF. The specific gravities of 0.589 for the SNG and 0.587 for the natural gas were nearly identical. The Wobbe number for SNG, 1341, is within 0.1% of the 1343 Wobbe number of the natural gas.

The interchangeability indices show that all are within the preferred range except of I_Y, yellow-tipping, which is outside the limits. The I_Y was computed to be 0.943 whereas the preferred value should exceed 1.0. This would indicate possible yellow-tipping, and combustion tests confirmed a slight tendency to yellow-tip. The amount, however, was not considered objectionable and we consider the gas interchangeable.

3. SNG After Two-Stage Gasification and CO_2 Removal

In the British Gas Council process for SNG from naphtha, the methane content can be increased by adding a hydrogasification step. Figure 3 shows this gas composition after CO_2 removal. The heating value is 934 BTU/CF compared to 869 BTU/CF for the single-stage treatment. The Wobbe numbers are within 6% which indicate the flow rate should be satisfactory. The interchangeability indices are within the preferred ranges. Combustion tests confirmed that this gas is completely interchangeable with the natural gas.

4. Above SNG Enriched with Ethane

The SNG from two-stage gasification was enriched with ethane to 1030 BTU/CF to bring the heating value to that of the natural gas. Figure 4 shows the pertinent data. Note that the Wobbe numbers are within 1%, indicating satisfactory heat input flow rate through a fixed orifice. You will recall that 10% is acceptable.

The interchangeability indices show that I_L and I_F are within the preferred limits. The yellow-tipping index, I_Y, is outside the preferred limit of 1.0 or above. This means that the gas may show yellow-tipping and indeed this was confirmed by combustion tests. However, the amount of yellow-tipping was not objectionable and we consider the gas interchangeable.

5. SNG from Coal Gasification

The last case considered was SNG from coal gasification. Figure 5 shows the gas composition expected from the HYGAS process under development at the Institute of Gas Technology. This SNG consists predominately of methane, 93%, and about 6-1/2% hydrogen. Its heating value of 968 BTU/CF and specific gravity of 0.545 yields a Wobbe number of 1312. This is within 2.4% of the natural gas, well inside the 10% acceptable limit.

The interchangeability indices show that I_L, the lifting index, is 1.0 compared to the preferred value of less than 1.0. The other indices are within the preferred range.

Combustion tests showed this SNG to have a slight tendency to lift, confirming the I_L indication. However, the lifting was so slight that we considered the gas completely interchangeable.

CONCLUSIONS

A wide range of gas compositions produced from liquid and solid fuels was found to be interchangeable with natural gas. SNG having a heating value ranging from 869 BTU/CF to 1030 BTU/CF was shown to be interchangeable with a 1030 BTU/CF high methane natural gas.

The A.G.A. interchangeability indices plus the Wobbe number can predict substitutibility. Combustion tests using a wide variety of burners confirmed the validity of these empirical indices.

REFERENCES

[1] Grumer, Joseph, and Harris, Margaret E., *Exchangeability of Synthetic Gases from Solid Fuels with Pipe Line Natural Gas*, Bureau of Mines Report of Investigation 6629, U.S. Department of the Interior, 1965.

[2] Research Bulletin 36, *Interchangeability of Other Fuel Gases with Natural Gas*, American Gas Association, 1952.

[3] *Future Gas Requirements of the United States, Volume 4, October, 1971*, Future Requirements Agency, Denver Research Institute, University of Denver, Denver, Colorado.

[4] *Gas Utility and Pipeline Industry Projections*, Department of Statistics, American Gas Association, Inc., Washington, D. C.

[5] Davies, H. S., Lacey, J. A., and Thompson, B. H., *Process for the Manufacture of Natural-Gas Substitutes*, Research Communication GC 155, The Gas Council, London, (1968).

TABLE I

U.S. Gas Requirement - 1970

	Trillions of Cubic Feet	% of Total
Residential	4.94	23.1
Commercial	1.96	9.1
Industrial	5.94	27.7
Electric utility	3.92	18.3
Interruptible	3.09	14.4
Other	1.58	7.4
Total	21.43	100.0

Source: *Future Gas Requirements, October, 1971.*[3]

TABLE II

Gas Customers - 1970

	Thousands	% of Total
Residential	38,303	91.8
Commercial	3,158	7.6
Industrial and others	249	.6
Total	41,710	100.0

Source: American Gas Association, Inc., Department of Statistics.[4]

TABLE III

Interchangeability Factors

$$\text{Wobbe No.} = \frac{\text{heating value}}{\sqrt{\text{specific gravity}}} = \frac{h}{\sqrt{d}}$$

I_L = under 1.0; above 1.06

I_F = under 1.18; above 1.2

I_Y = above 1.0; under 0.8

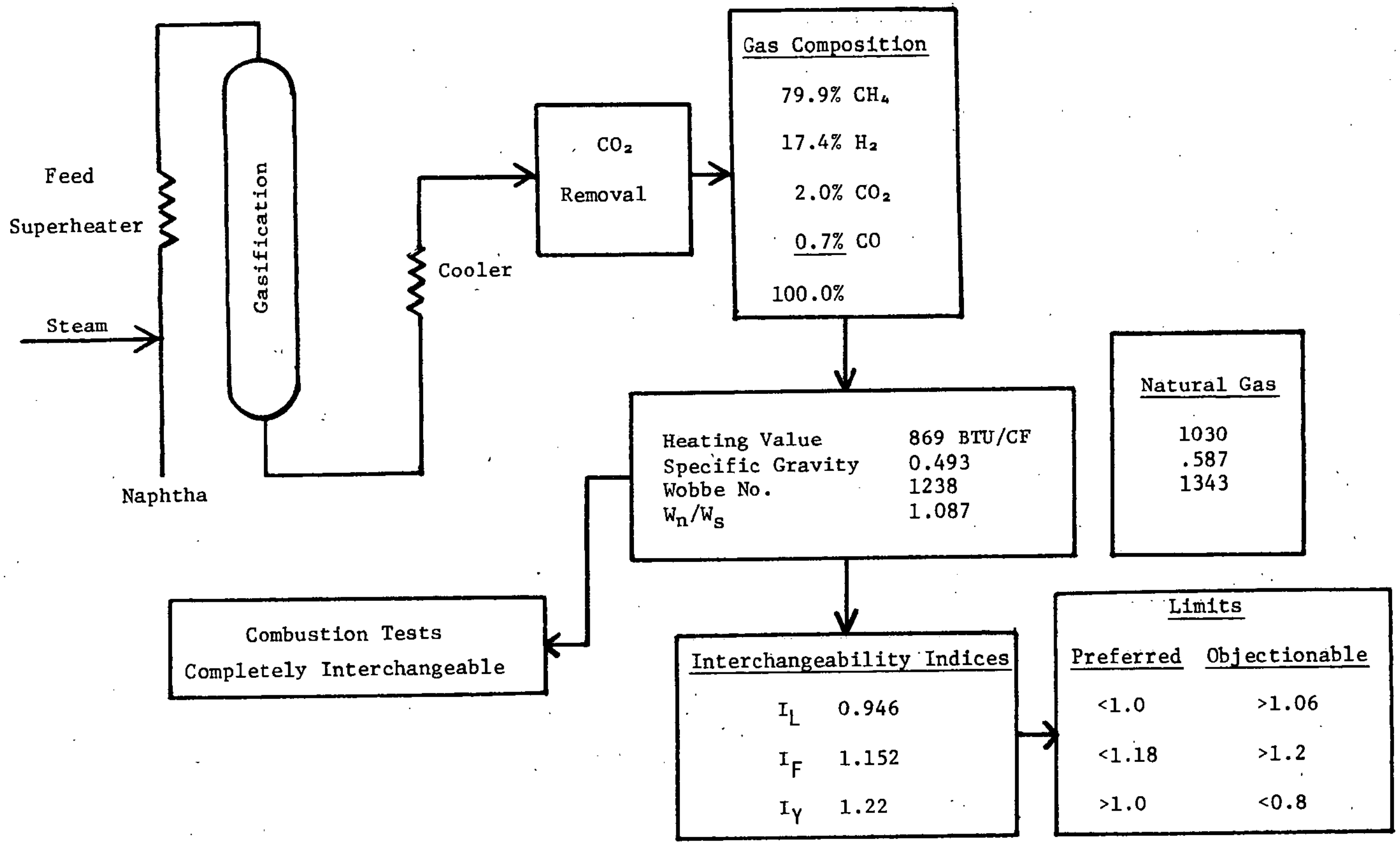

FIGURE 1: SNG AFTER SINGLE-STAGE GASIFICATION AND CO_2 REMOVAL

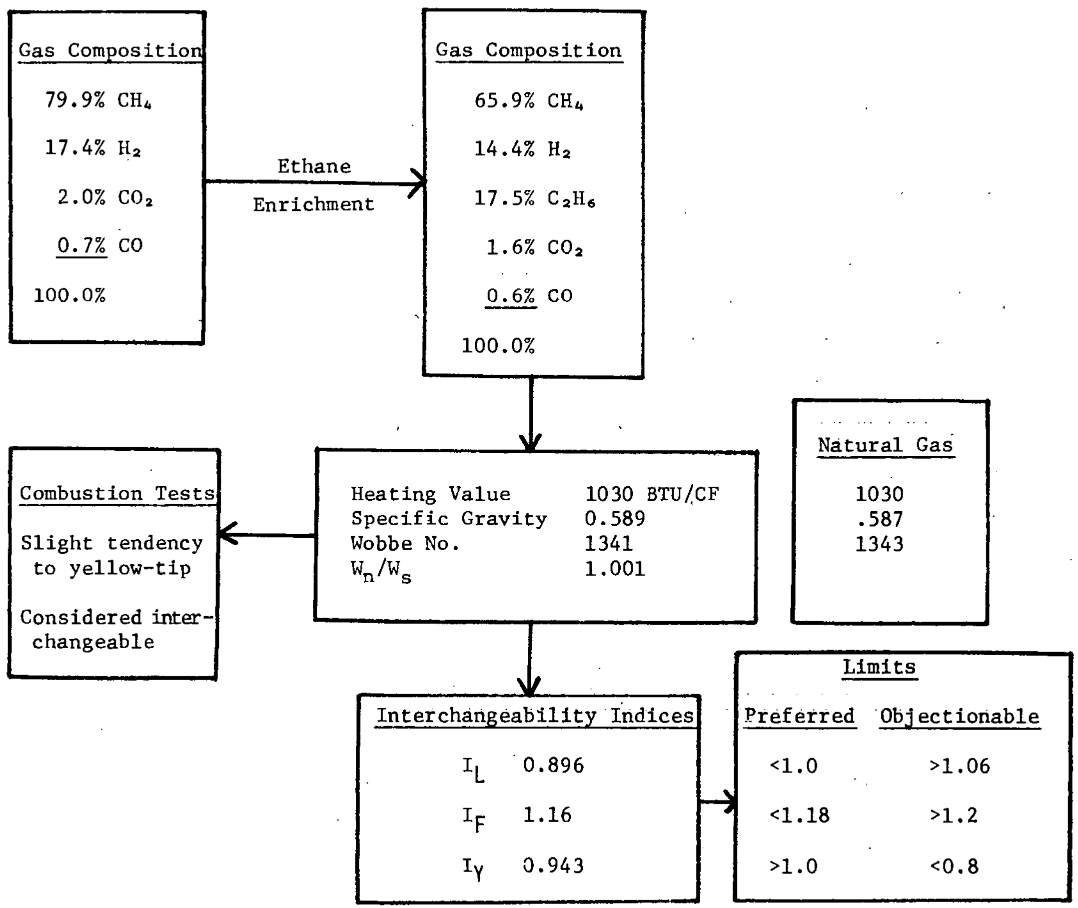

FIGURE 2: SNG ENRICHMENT WITH ETHANE

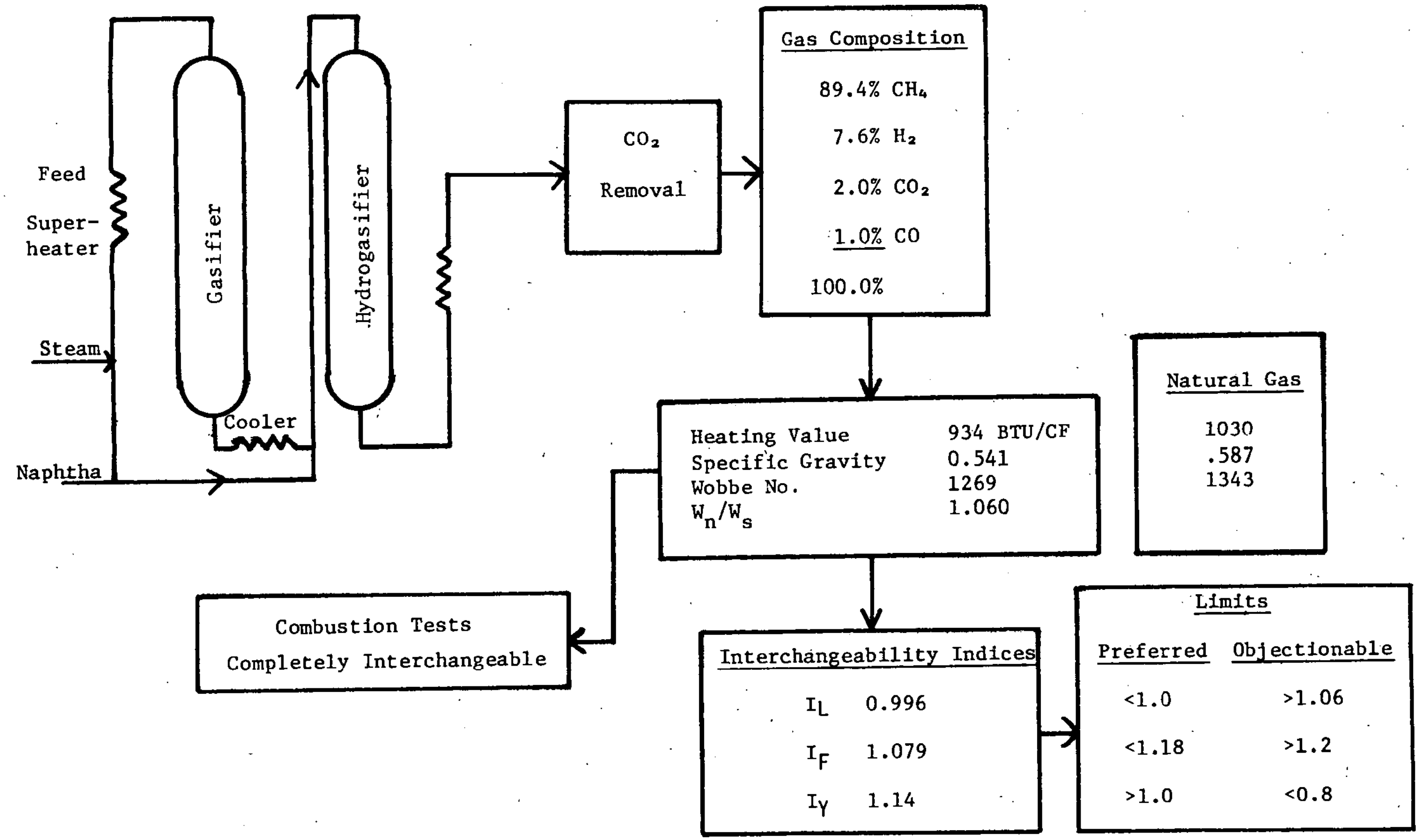

FIGURE 3: SNG AFTER TWO-STAGE GASIFICATION AND CO_2 REMOVAL

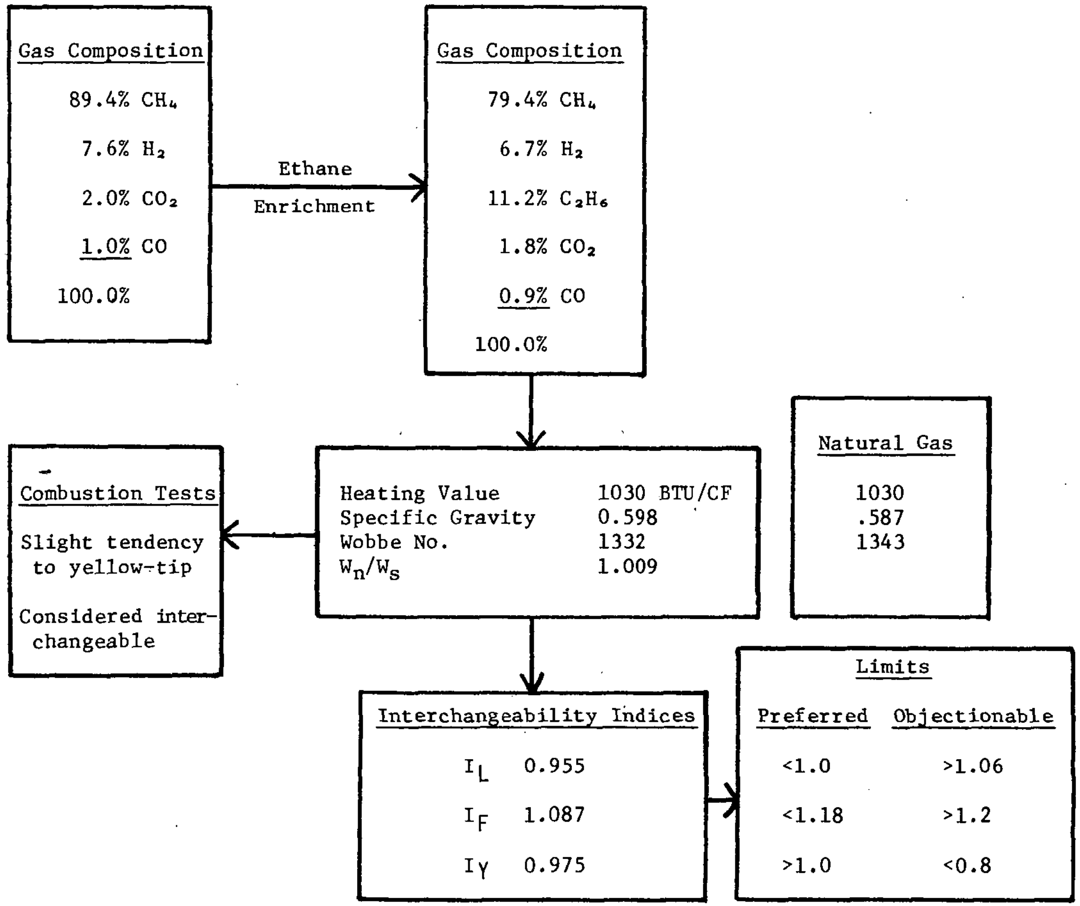

FIGURE 4: SNG AFTER ENRICHMENT WITH ETHANE

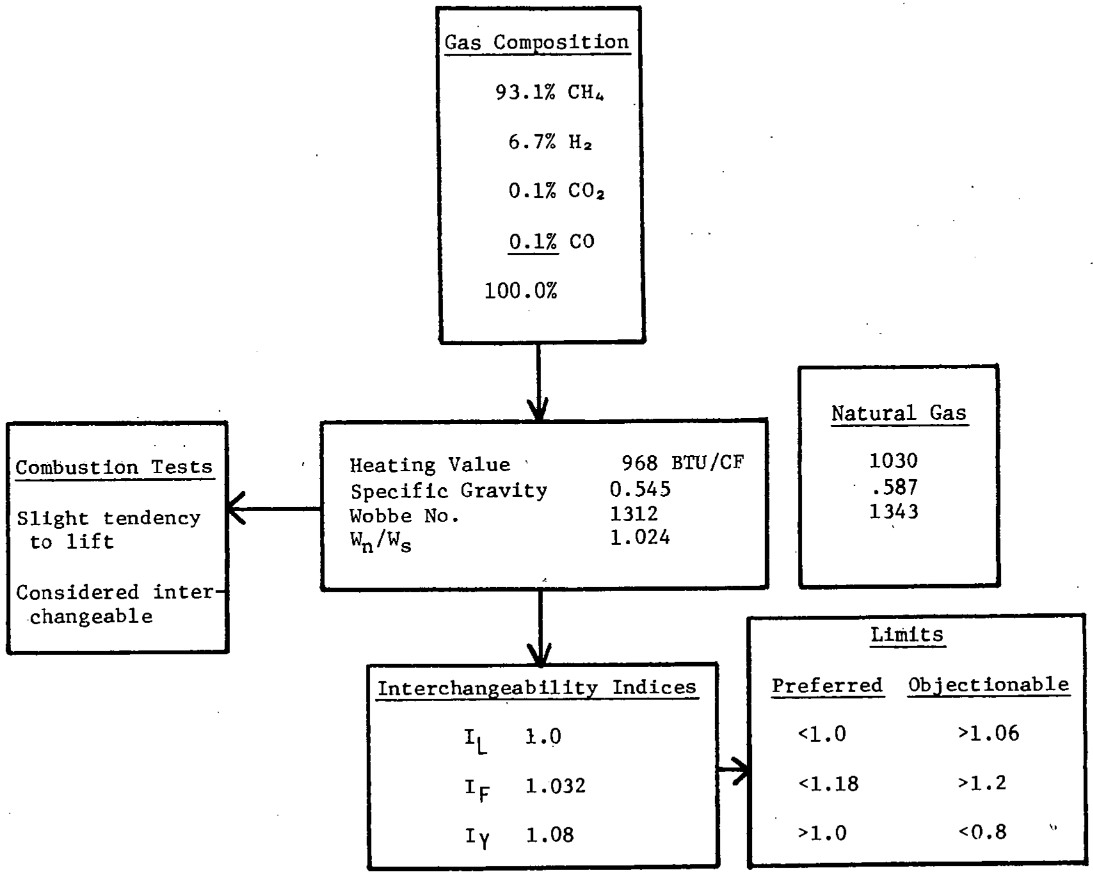

FIGURE 5: SNG FROM COAL GASIFICATION