This invention relates to a method of improving the production of acetylene by the electric arc process.

It is known to produce acetylene by passing hydrocarbons through an electric arc at elevated temperatures. It was subsequently found that the addition of hydrogen or other inert gases tended to suppress the formation of carbon within the reactor; however, since these gases are not consumed in the reaction they tend to dilute the product. The rate of reaction is thereby increased thereby inhibiting its isolating the acetylene. The process ofDoukas, U.S. Patent 3,073,769, represents a technique to avoid undesirable accumulation of carbon on the cathode by magnetically rotating the electric arc and controlling the current supplied; however, the anode still tends to collect carbon and finely divided carbon is still present in the product gas.

The manufacture of acetylene from hydrocarbons, even when carried out as outlined above, is still open to improvement in yield, power consumption, and by-product formation. The chief by-products are diacetylene, which must ordinarily be removed from the acetylene by special procedures, and carbon, which must be removed mechanically in mass form from the reactor and must also be removed in finely divided form from the product gas. Although carbon is an important by-product in making acetylene from methane, it is formed in such large amounts in the pyrolysis of the higher hydrocarbons, such as those in fuel oils, that the process is uneconomical without modification.

It has unexpectedly been found that, in operating arc reactors of this type for making acetylene, the conversion of the hydrocarbon to acetylene is increased and that the power consumption (per pound of acetylene) and the formation of by-products such as carbon and diacetylene is substantially reduced by this invention. The inventive improvement is in a process for making acetylene by the pyrolysis of a hydrocarbon in an electric arc furnace having a carbon cathode in the form of a round rod, a coaxially aligned elongated cylindrical metal anode extending beyond the end of the cathode and having an internal diameter greater than the diameter of the cathode and a rotating electric arc formed from the tip of the cathode and striking the anode in a zone between the tip of the cathode, which process comprises passing the hydrocarbon and hydrogen gas in a gaseous stream under a pressure of at least 2 inches of mercury absolute through the furnace past the cathode tip through the electric arc, exposing the end portion of the cathode to the gaseous stream over a length of at least about 2 times its diameter, strongly cooling the shank of the cathode above said end portion to a temperature below about 1100° C., applying a direct electric current to the cooled shank of the cathode to form and maintain the electric arc, adjusting the strength of said current within the safe current-carrying capacity of the cathode in accord with the furnace pressure and the diameter of the cathode to provide a current of at least about 1400 amperes per inch of cathode diameter at which the cathode tip burns off steadily at a rate of at least 2 inches of length per hour and the diameter of the cathode is maintained substantially constant, and advancing the cathode into the furnace at the rate at which it is consumed so as to maintain said exposed end portion, which improvement comprises controlling the amounts of hydrocarbon and hydrogen gas in a feed mixture such that the ratio of total hydrogen atoms in the components of said mixture to the carbon atoms is greater than 4:1 but less than 5:1. The benefits of the invention are greatest when the said ratio is between 4.5:1 and 4.7:1. This invention is most unexpectedly beneficial when the average number of carbon atoms in the hydrocarbon feed is greater than about five. At this point the formation of carbon becomes excessive and the mere addition of equal volumes of hydrogen would be totally insufficient to achieve maximum benefit. For example, if vaporized petroleum is to be the feed hydrocarbon, the use of less than 400% by volume of hydrogen will be insufficient. When fuel oil is the hydrocarbon, the average number of carbons is about 12 to 13.

The hydrocarbon converted to acetylene may be either saturated or unsaturated, straight or branched-chain or cyclic. It should, preferably but not necessarily, be perfectly volatile at the temperature at which it is introduced into the reactor. The most suitable feeds are obviously those which are readily and continuously available at low cost. Examples are gases of the paraffin series, such as methane, ethane, and propane, and liquid petroleum fractions, fuel oils, and solvents, such as the polynuclear aromatic compounds and coal, in powdered form. Mixtures, such as natural gas and the various commercial fuels, including coal, are entirely satisfactory. The fuel oils, for example, may contain large proportions of cyclopentane and aromatic hydrocarbons. Waste hydrocarbons are suitable if they come within the above limits, and are of constant composition. Highly unsaturated hydrocarbons are good sources of acetylene (e.g., divinylacetylene) when diluted with the amounts of hydrogen required by the definition of the invention. Non-volatile solids and liquids are introduced in hydrogen into the reactor in finely divided form.

The form of the reactor is described in U.S. Patent 3,073,769. The arc rotates at high angular velocity, usually between 5,000 and 10,000 revs. per sec. The hydrogen used in the feed is conveniently taken from the product gas after the separation of acetylene and other product hydrocarbons. A convenient method of operating is to use the by-product hydrogen from which the by-product hydrocarbon gases, mostly methane, have not been removed. These hydrocarbons form acetylene in the arc and are included in the calculation of the carbon to hydrogen ratio.

The present invention is not in the form of the apparatus nor in the conditions under which it is operated. The use of hydrogen in the proportions taught and in the present invention may be used to advantage with any operating conditions of mass flow, pressure, power input, magnetic field strength, voltage, and the like which yield acetylene. Obviously, however, selected conditions, such as are given in U.S. Patent 3,073,769, are preferred.

Acetylene is made in the following examples in tubular arc furnaces with electro-magnetically rotated arc, of the kind shown in U.S. Patent 3,073,769. The anode is a vertical cylinder, internally water-cooled. The cylindrical cathode is of consolidated graphite held in a water-cooled holder by means of shoes which provide electrical and thermal contact and allow the cathode to be advanced further into the furnace as it is consumed. All of which is shown in the U.S. patent referred to above. An electromagnet surrounds the anode, usually somewhat below the tip of the cathode. When so located, in addition to rotating the arc at a high angular velocity about the common axis of the two electrodes, the magnet deflects the arc somewhat down-stream from the cathode tips. The feed consisting of hydrogen and hydrocarbon in specified proportions preheated and at a fixed sub-atmospheric pressure, is passed downward through the rotating arc and on
through the anode cylinder at the bottom of which it is quenched with sprays of water. The exit gas consists of hydrogen, acetylene and minor amounts of other hydrocarbons mostly methane, ethane, ethylene, and diacetylene, with suspended carbon.

The invention will now be described with reference to the following examples of specific embodiments thereof wherein parts and percentages are by weight unless otherwise specified.

**EXAMPLE 1**

(A) The reactor used is formed by a copper anode 3.5 inches in diameter, with a co-axial graphite cathode 0.625 in. in diameter, the other features being as described above.

The hydrocarbon feed is a fuel oil of specific gravity 0.850, refractive index 1.4755, mid-bolling point 265° C, and approximate molecular weight 202, containing about 86.7% carbon. This oil at the rate of 250 lbs. per hr, is vaporized, mixed with hydrogen, and preheated to about 600° C. The hydrogen feed is at such a rate as to give a ratio of 4.6 total atoms of hydrogen in both the hydrocarbon and the hydrogen carrier gas per atom of carbon.

The pressure is maintained at 350 mm. The mass flow of hydrocarbon is 3700 lbs. per hr. and per sq. ft. The potential difference between cathode and anode is 625 volts and the current is 1040 amperes, corresponding 3.0 kilowatt hours per lb. of carbon in the feed. The magnetic field is 1200 gauss at the tip of cathode. The carbon forming on the anode is continuously removed by the mechanical scraping device. See Table I for a listing of typical quantitative results.

(B) The reactor used in Part A is operated with the same hydrocarbon feed under the same conditions except that the feed of hydrogen is reduced so that the ratio of total hydrogen to carbon atoms is 4.0 and the current and voltage are somewhat different but still corresponding to an input of 3.0 kilowatt hours per pound of carbon in the feed. See Table I for typical quantitative results.

(C) Part B is repeated, but with 5.0 hydrogen atoms per atom of carbon. See Table I.

**EXAMPLE 2**

Example 1, Parts A, B, and C, is carried out in the same reactor in the same way but with a magnetic field of 1800 gauss at the cathode tip and a power input of 2.2 kilowatt-hours per lb. of carbon in the feed. The ratio of hydrogen to carbon is varied as in Example 1, Parts A, B, and C. See Table I for typical results.

**EXAMPLE 3**

Example 1, Parts A, B, and C, is repeated except that the magnetic field is 1800 gauss at the cathode tip and the power input is 3.0 kilowatt-hours per pound. See Table I for typical results.

<table>
<thead>
<tr>
<th>Table I—Acetylene from Fuel Oil</th>
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<tbody>
<tr>
<td>No.</td>
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<td>C</td>
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</table>

**EXAMPLE 4**

The furnace used has a copper anode 2.9 inches in diameter, with a 0.5 inch graphite cathode. The other features being as in the above general description.

The hydrogen feed is a natural gas typically containing about 93.5% methane and is fed at a rate of 180 lbs. per hr. without preheating, along with one volume of hydrogen for four volumes of the natural gas (i.e., the mixture is about 20% hydrogen gas by volume). The ratio of total hydrogen to carbon atoms is about 4.3, assuming that the gas contains about 5% ethane and about 2% propane. The mass flow is about 4000 lbs. per hr. and per sq. ft., and the power input is 3.0 kilowatt hrs. per lb. of feed, with the voltage about 530. The magnetic field strength is 2000 gauss and the pressure 350 mm. to illustrate the improvements brought about by the use of hydrogen, these values are also given for operation without added hydrogen but otherwise the same. In using the above-described methane without additional hydrogen, the hydrogen to carbon ratio is about 3.9.

When the ratio of H:C is adjusted to 4.3 by adding hydrogen gas, the conversion to acetylene is typically about 75.1% based on the percentage of carbon converted thereto. When the added hydrogen is omitted (H:C being about 3.9), the typical conversion drops to about 71.0.

The various other hydrocarbons already mentioned, including powdered coal, can be employed in the above examples with modifications readily apparent to one skilled in the art as long as the proper hydrogen to carbon ratio is observed.

Without knowledge of applicant's invention, one skilled in the art would ordinarily avoid the use of the large volumes of hydrogen necessary to adjust the H:C ratio (particularly when employing high molecular weight hydrocarbons) because of the consequent hydrogen dilution of the acetylene product.

As many widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that this invention is not limited to the specific embodiments thereof except as defined in the appended claims, and all changes which come within the meaning and range of equivalence are intended to be embraced therein.

What is claimed is:

1. In a process for making acetylene by the pyrolysis of a hydrocarbon in an electric arc furnace having a carbon cathode in the form of a round rod, a coaxially aligned elongated cylindrical metal anode extending beyond the end of the cathode and having an internal diameter greater than the diameter of the cathode and a rotating electric arc formed from the tip of the cathode and striking the anode in a zone beyond the tip of the cathode, which process comprises passing the hydrocarbon and hydrogen gas in a gaseous stream under a pressure of at least 2 inches of mercury absolute through the furnace past the cathode tip through the electric arc, exposing the end portion of the cathode to the gaseous stream over a length of at least about 2 times its diameter, strongly cooling the shank of the cathode above said end portion to a temperature below about 1100° C, applying a direct electric current to the cooled shank of the cathode to form and maintain the electric arc, adjusting the strength of said current within the safe current-carrying capacity of the cathode in accord with the gas pressure and the diameter of the cathode to provide a current of at least about 1400 amperes per inch of cathode diameter at which the cathode tip burns off steadily at a rate of at least 2 inches of length per hour and the diameter of the cathode is maintained substantially constant, and advancing the cathode into the furnace at the rate at which it is consumed so as to maintain said exposed end portion; the improvement which comprises controlling the amounts of hydrocarbon and hydrogen gas such that the ratio of total hydrogen atoms in the compo-
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ents of said mixture to the carbon atoms is greater than 4:1 but less than 5:1.

2. A method as defined in claim 1 wherein said hydro-
carbon has an average of at least five carbon atoms.

3. A method as defined in claim 1 wherein the hydro-
gen to carbon ratio is between 4.5:1 and 4.7:1.

4. A method as defined in claim 2 wherein the hydro-
gen to carbon ratio is between 4.5:1 and 4.7:1.

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