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Vestal

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[54] **PROCESSING OF COAL TO PRODUCE LIQUID AND VAPOROUS HYDROCARBONS**

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[52] **U.S. Cl.** ..... **204/168,** 48/65, 48/202, 204/73 R, 208/8

[51] **Int. Cl.** **B01k 1/00**

[58] **Field of Search** ..... 48/65, 197 R, 202, 210, 48/DIG. 7; 204/168, 172, 173, 190, 170, 73 R; 208/8

[56] **References Cited**

UNITED STATES PATENTS

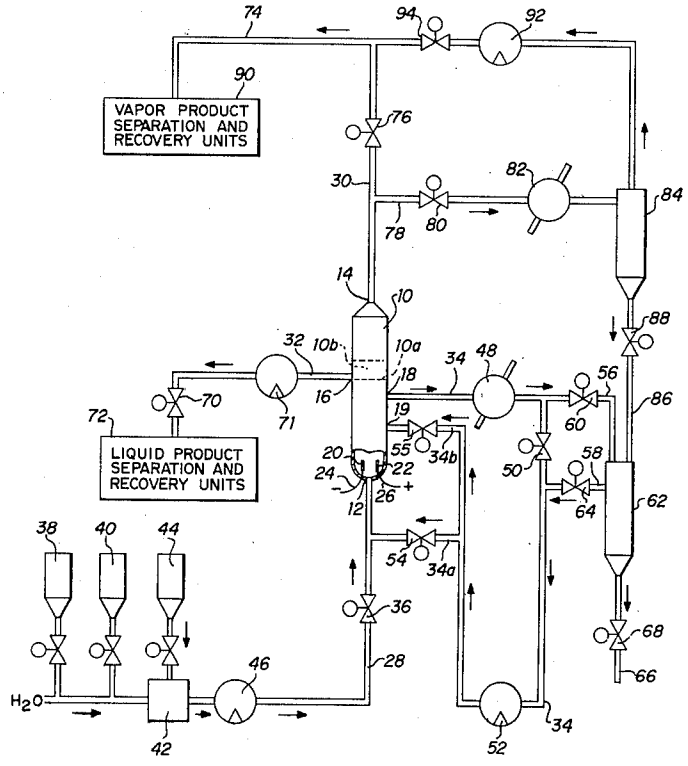
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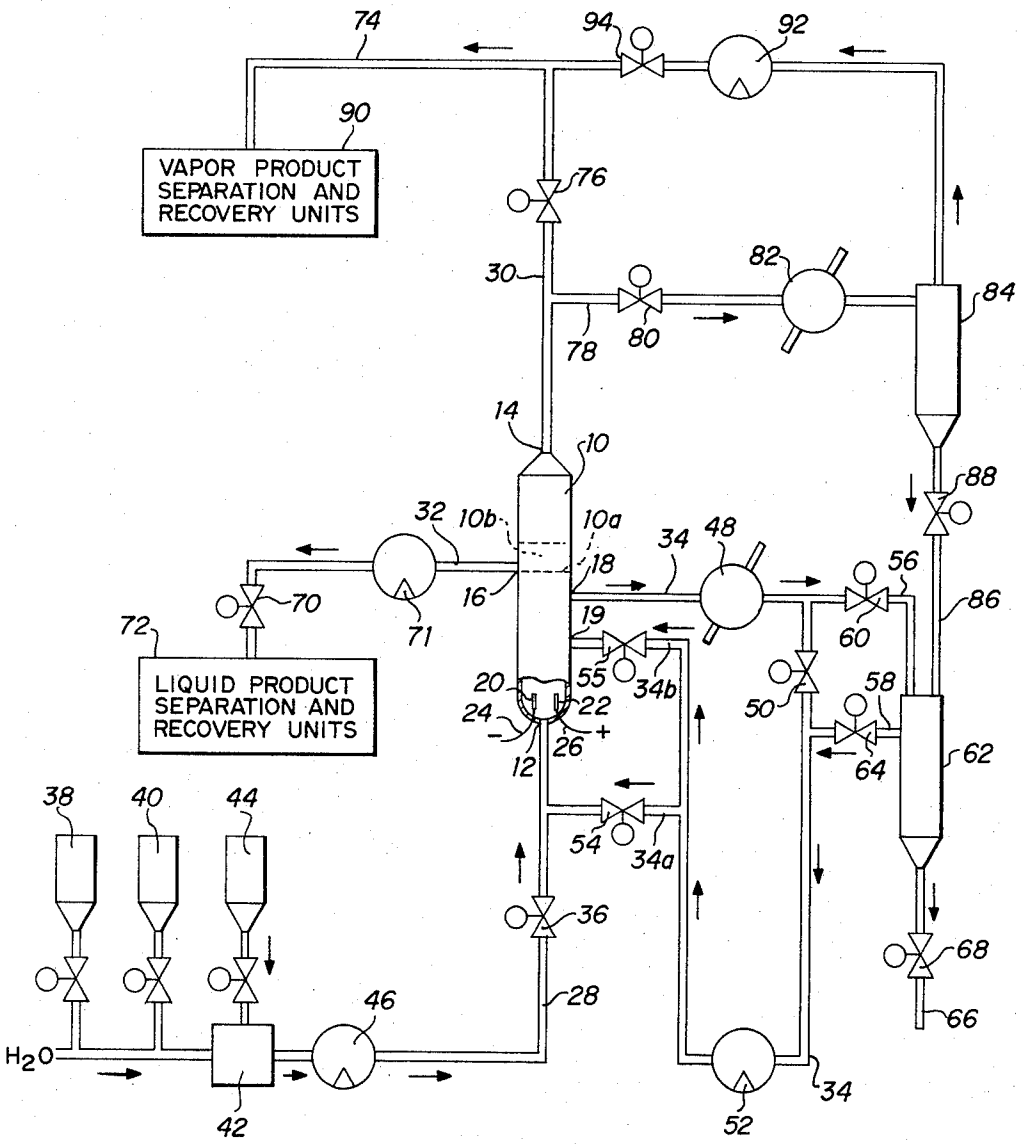
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[57] **ABSTRACT**

Liquid and vaporous hydrocarbons are formed from coal by initially forming an aqueous slurry of comminuted coal and thereafter passing the aqueous slurry through a high energy zone — such as formed between electrodes to cause decomposition of the coal into lower molecular weight hydrocarbons. Next, the slurry containing the reaction products from the high energy zone are passed instantaneously into a cooled aqueous medium and the liquid and vaporous hydrocarbons are removed therefrom. In one embodiment, electrolysis of the water between the electrodes forms hydrogen which is reacted with unsaturated decomposition products of coal to form hydrocarbon components. In another aspect, a pyrophoric metal, such as a mixture of Fe_3O_4 and aluminum is admixed with the coal in the high energy zone to further increase the energy input thereto.

17 Claims, 1 Drawing Figure




74
94
92
90
VAPOR PRODUCT SEPARATION AND RECOVERY UNITS
76
30
82
84
78
80
14
10
88
32
10b
10a
34
48
56
18
16
70
71
86
72
19
LIQUID PRODUCT SEPARATION AND RECOVERY UNITS
55
34b
50
58
20
24
22
26
12
64
62
38
40
44
54
34a
36
68
28
46
66
H2O
42
52
34

PROCESSING OF COAL TO PRODUCE LIQUID AND VAPOROUS HYDROCARBONS

This invention relates to processes for converting coal into other valuable chemical components. In another aspect, this invention relates to a method and apparatus for processing coal to obtain liquid and/or vaporous hydrocarbons therefrom.

Most of the hydrocarbons and hydrocarbon derivatives utilized by industry are obtained from petroleum. While various processes are known for converting coal into lower molecular weight hydrocarbons, such processes have not heretofore found widespread use because of the general availability of crude oil and the more efficient and economical processes which have been developed for processing crude oil to obtain hydrocarbons and hydrocarbon derivatives therefrom. Furthermore, due to the growing worldwide energy shortage which is particularly acute in the United States, there is a great demand for efficient and economical processes for deriving hydrocarbons and hydrocarbon derivatives from coal.

It is known that anthracite coals are made of a complex structure and have a rather large fraction of polynuclear aromatics and a small fraction of aliphatic groups. On the other hand, typical bituminous coal, while again being an exceedingly complex structure does contain a large proportion of aliphatic hydrocarbon chains in which the hydrogen to carbon ratio is 2 to 1 and a relatively small fraction of polynuclear aromatics in which the hydrogen to carbon ratio is less than 1.

In general, commercially utilized processes for converting coal into lower molecular weight components include pyrolysis of the coat. It is known that many complex chemical reactions take place during coal pyrolysis or coking operations, but in general, decomposition and polymerization reactions take place. The typical coking operation for coal includes heating the coal to a temperature above about 700°F over a relatively long time period. This results in the weaker bonds rupturing first and with increasing temperature successively stronger bonds begin to rupture. Furthermore, in general, the hot atmosphere maintained around the coal results many times in the decomposition products further decomposing in the vaporous or gaseous state.

It has been recognized in U.S. Pat. No. 3,384,467 that if coal absorbs heat energy at a rate greatly exceeding the heat transfer rate typically used in coking, a substantial severance of the high energy basic bond structure, and particularly the carbon bonds with consequent production of lower molecular weight products is affected. However, even with such process, there is a problem of removal of decomposition products before they become further decomposed in the presence of the high energy source.

According to one object of this invention, a novel method and means are provided for converting coal to lower molecular weight components.

Another object of this invention is to provide an improved coal conversion process wherein the coal is converted to liquid and/or vaporous hydrocarbons.

Another object of this invention is to provide an improved process for converting coal to liquid and/or vaporous hydrocarbon material which includes subjecting coal to high energy conditions and thereafter repidly quenching the reaction and thereby recovering the reaction products.

According to the invention, a method is provided for converting coal into liquid and/or vaporous components which includes initially forming an aqueous suspension of comminuted coal and thereafter passing the suspension through a high energy conversion zone while submerged under an aqueous medium to effect decomposition of the coal into volatilized components which are immediately cooled as they pass from the high energy zone through the aqueous medium.

According to one embodiment of the subject invention, the conversion energy for decomposing the coal comprises an electric arc formed between at least two spaced electrodes.

According to another embodiment of the subject invention, at least a pair of electrodes (an anode and cathode) are disposed adjacent the high energy conversion zone and are operating in the electrolysis mode to thereby furnish hydrogen for reaction with said volatilized components.

According to still another embodiment of this invention, the high energy conversion zone comprises at least 2 spaced electrodes (an anode and cathode) operating in an electrolysis mode within an aqueous medium, thereby forming hydrogen at the cathode and the aqueous slurry containing the comminuted coal which is passed therebetween also contains pyrophoric material which is ignited in the presence of the electrodes and thereby imparts high intensity energy to the comminuted coal to cause decomposition thereof, the unsaturated decomposition products thereby reacting with the hydrogen to form liquid and/or vaporous hydrocarbon products.

Thus, the subject invention provides a process of imparting a high rate of energy to comminuted coal disposed within an aqueous medium without vaporizing the entire aqueous medium, to thereby allow the decomposition products to be instantaneously cooled within the aqueous medium as they are formed.

This invention can be more easily understood from a study of the drawing which comprises a schematic representation of an apparatus suitable for converting coal and which embodies the principles of the subject invention.

Now referring specifically to the drawing, this invention will be described in relation to the conversion of coal into liquid and/or vaporous components. It is noted that while the invention will be described in terms of the conversion of coal which normally encompasses both anthracite and bituminous coal, the word "coal" is used herein to include similar materials such as tar, lignite, charcoal and coke, for example. The preferred material which is converted in the scope of this invention is bituminous coal and/or anthracite coal.

Now referring to the drawing, an apparatus is schematically illustrated which can be utilized to convert coal in accordance with several embodiments of the subject invention. In each embodiment, a means is provided whereby particulate coal while submerged within an aqueous medium is subjected to an instantaneous energy input which will heat at least the surface of the coal particles to a temperature above about 700°F and generally from about 700°F to about 2,000°F. The decomposition products are emitted immediately into a body of the liquid aqueous medium and pass upwardly therethrough and are then separated therefrom.

As shown, coal converter **10** comprises an upright, elongated enclosed vessel having a liquid inlet **12** at the

lower end thereof; vapor product outlet **14** at the upper end thereof; a liquid product outlet **16** adjacent the midportion thereof; a liquid recycle outlet **18** adjacent the midportion of vessel **10** but below the liquid product outlet **16** and a liquid inlet **19** disposed between liquid recycle outlet **18** and liquid inlet **12.** Electrodes **20** and **22** are positioned adjacent liquid inlet **12,** and are connected to lead means **24** and **26,** respectively, for applying electric power thereto. As shown, electrode **20** serves as a cathode and electrode **22** as the anode.

As shown in the drawing, feed inlet conduit **28** operatively communicates with liquid inlet **12,** and vapor outlet conduit **30** operatively communicates with vapor outlet **14.** Similarly, liquid outlet conduit **32** operatively communicates with liquid product outlet **16,** and recycle conduit outlet **34** operatively communicates with liquid recycle outlet **18.** More specifically, recycle conduit **34** communicates from liquid recycle outlet **18** to feed inlet conduit **28** via leg **34***a* and liquid inlet **19** via leg **34***b*, as schematically illustrated in the drawing.

To further describe the structure of the apparatus shown in the drawing, the feed inlet conduit **28** is designed to receive a flow of water therethrough and operatively communicate with a series of solids feeder units **38** and **40,** and has mixing chamber **42** operatively disposed therein. Solids feeder unit **44** operatively communicates with mixing chamber **42.** Furthermore, pump **46** and valve **36** are disposed within feed inlet conduit **28,** as illustrated in the drawing. Recycle conduit **34** has cooler **48,** valve **50,** and pump **52,** valves **54** and **55** operatively disposed therein. Valves **54** and **55** are operatively positioned within legs **34***a* and **34***b*, respectively. Valve **50** is disposed within recycle conduit **34** between the junction of conduits **56** and **58** therewith. Conduit **56** has valve **60** operatively disposed therein and communicates to the upper region of liquid solids separator **62.** Conduit **58** has valve **64** operatively disposed therein and communicates with the upper mid-portion of liquid solids separator **62.** The bottom of liquid solids separator **62** communicates with outlet conduit **66** which has valve means **68** operatively disposed therein.

Liquid product outlet conduit **32** has valve **70** and pump **71** operatively disposed therein and communicates with liquid product, separation, and recovery units **72.** Liquid product separation and recovery units **72** can comprise any conventional apparatus known in the art for separating liquid hydrocarbon components and recovering the separated components. Such apparatus is old and well known in the art and can include fractionation, absorption and the like and is not novel and part of the subject invention.

Gaseous product outlet conduit **30** communicates from gaseous outlet **14** to conduit **74** and has valve **76** operatively disposed therein. Conduit **78** communicates with gaseous product outlet conduit **30** at a point between gaseous outlet **14** and valve **76.** Conduit **78** has valve **80** and cooler **82** operatively disposed in series therein and communicates with the upper midportion of vapor liquid separator **84.** Conduit **86** has valve **88** operatively disposed therein and communicates from the bottom of vapor liquid separator **84** to the top of liquid-solids separator **62.** Conduit **74** communicates between the upper portion of liquid-vapor separator **84** to gaseous product separation and recovery units **90** and has pump **92** and valve **94** operatively positioned therein. Vapor product separation and recovery units **90** can comprise any conventional apparatus including separation, fractionation and adsorption and scrubbing towers known in the art for separating gaseous components and particularly, hydrocarbon components. The vapor product separation and recovery units **90** can be varied as desired, but any old, well known combination of units can be used to separate the product gases and such conventional units in and of themselves, do not form a part of the subject invention.

Generally, in the operation of the apparatus is formed shown in the drawing, a high energy conversion zone isformed between electrodes **20** and **22.** Furthermore, an aqueous stream containing between about 2 and about 60% solids is continuously delivered through inlet **12** and thereby through the high energy zone. Simultaneously, the aqueous stream is continuously delivered from conduit **34***b*to inlet **19** and serves to cool the hot reactants which pass from the high energy zone. This is accomplished by constantly withdrawing aqueous medium via liquid recycle outlet **18** into conduit **34,** through valve **50** (with valves **60** and **64** closed), pump **52,** and then through conduit legs **34***a* and **34***b*. Valves **54** and **55** are positioned so that the desired proportions of the liquid flowing through conduit **34** are split and a first portion passes through leg **34***a* and the second portion through leg **34***b*. Generally, valves **54** and **55** are open to allow about half of the recycle fluid flow through leg **34***a* and about half to flow through leg **34***b*. Coal converter **10** can be operated under any desired pressure range and generally, under normal atmospheric pressure. Thus, cooler **48** maintains the aqueous slurry at a temperature below about 212°F, even though substantial portions of the water which pass through leg **34***a*, through conduit **28** and inlet **12** will vaporize. As stated, generally, from about 2 to 60 volume percent of the fluid maintained within coal converter **10** is solids and generally, mostly comminuted coal. Conduit **28** delivers makeup portions of solid material to inlet **12** when valve **36** is open. Thus, the solids content of the fluid flowing through valve **36** can be substantially greater then 60 percent by volume, but once it is diluted by the fluid flowing through leg **34***a* should generally contain from about 2 to about 60 volume percent solids. Generally, it is preferred that comminuted coal be delivered via solids feeder unit **44** and other reactants be delivered via solids feeder units **38** and **40.** For example, catalysts or pyrophoric particulate metals.

According to one embodiment of this invention, an aqueous slurry of comminuted coal together with a pyrophoric material is passed through liquid inlet **12** and between electrodes **20** and **22,** which are operating in an electrolysis mode. More specifically, coal converter **10** is supplied with reactants by opening valve **36** and passing water into conduit **28.** Solids feeder unit **38** is actuated and supplies conduit **28** with powdered Fe_3O_4 to form an initial aqueous slurry. This slurry is then passed to the point adjacent solids feeder unit **40** wherein powdered aluminum is added thereto to form a second slurry. The second slurry is then passed into mixing chamber **42** which receives comminuted coal via solids feeder unit **44.** The resulting slurry is passed via pump **46** and valve **36** to inlet **12** of coal converter **10.** The resulting slurry can contain from about 2 to about 60 and preferably from about 5 to about 35% by volume total solids. Generally, the relative amount of pyrophoric metal in the slurry can be varied, depending

upon the products one desires from the reaction. Generally, the amount of pyrophoric materials, (Fe_3O_4 and Al) will be from about 0.01% by weight to about 10% by weight and preferably from about 0.02% by weight to about 2% by weight of the total weight of the coal in the slurry. Generally, it is preferred that stoichiometric amounts of aluminum and Fe_3O_4 be present in the slurry. Thus, while less than stoichiometric proportions of Fe_3O_4 and Al can be present, it is generally desired that the approximate stoichiometric proportion be present to satisfy the following equation:

$$3\ Fe_3O_4 + 8Al = 4Al_2O_3 + 6\ Fe.$$

Next, with valves **60** and **64** closed and valves **50** and **54** and **55** open, pump **52** is actuated to cause the liquid slurry within coal converter **10** to be constantly recycled. Cooler **48** and the flow through legs **34***a* and **34***b* are controlled to assure that the aqueous fluid within coal converter **10** is maintained in the liquid state except adjacent the high energy zone. Water is maintained at a constant level **10***a* as shown by broken line in the drawing.

The resulting slurry which is passed from leg **34***b* to conduit **28** passes through liquid inlet **12** and between the electrodes **20** and **22** which are operating in the electrolysis mode wherein substantial amounts of hydrogen are present adjacent cathode **20.** The contact of the slurry with the electrodes causes ignition of the pyrophoric material and an instantaneous heat input to at least the surface of the coal particles. The instantaneous heat input thereby causes degradation of the coal and the formulation of vaporized constituents. The contact of the free hydrogen at this point causes hydrogenation of vaporous unsaturated hydrocarbon specie. The vaporous reaction products are then passed upwardly from the high energy zone and through liquid water within coal converter **10** to cause cooling thereof. The water is maintained at less than its boiling point. For example, when coal converter **10** is operated under atmospheric conditions, the water is maintained at a temperature of less than 212°F, and the vaporous reactants are rapidly cooled as they are passed upwardly therewithin. Thus, the normally liquid hydrocarbon components are condensed and flow to the surface **10***a* of the water (the interface between hydrocarbon layer **10***b* and the water) within coal converter **10** and the Vaporous constituents are cooled but pass upwardly thereto to vapor outlet **14.**

With the apparatus as shown in the drawing, and with coal converter **10** operating under continuous process conditions, valve **36** is generally operated in response to a liquid level (or interface level) within coal converter **10** by control mechanisms not shown in the drawing. Thus, when level **10***a* is reached within coal converter **10,** valve **36** is closed and pump **46** together with solids feeder units **38, 40** and **44** are deactuated. However, during the continuous operation of the subject invention, recycle conduit **34** is maintained full of slurry at all times and pump **52** is continuously operating.

During the normal continuous recycle mode, valves **50, 54** and **55** are open and the aqueous slurry is passed through liquid recycle outlet **18** into recycle conduit **34** and through cooler **48** wherein the slurry is cooled. Thereafter the slurry is passed through pump **52** into conduit legs **34***a* and **34***b*. The slurry from conduit leg **34***a* passes back into feed inlet conduit **28** and through liquid inlet **12** and between electrodes **20** and **22.** The slurry from conduit leg **34***b* is passed back into coal converter **10** above electrodes **20** and **22.** When this is accomplished, residual amounts of the pyrophoric material in the slurry passed through leg **34***a* will ignite adjacent electrodes **20** and **22** to cause further conversion of the coal particles.

Liquid hydrocarbonaceous materials floating on top of the water **10***a* are removed via liquid product outlet **16** and pass to conventional liquid product separation and recovery units **72** via pump **71** and valve **70.** The liquid products can comprise aliphatic and aromatic fractions depending upon the type of feed and the processing condition. Typical products can include straight and branched chain paraffinic hydrocarbons and aromatics such as benzene. The vaporous products which pass through vapor outlet **14** generally comprise the lower molecular weight hydrocarbons such as methane, ethane, propane, butane, ethylene, butylene, propylene, acetylene, as well as carbon monoxide, hydrogen, and water vapor, for example. The relative quantity of vaporous to liquid products will vary with the feed and process conditions. Preferably, with valve **76** closed and valve **80** open, the vaporous materials will pass from conduit **30** into conduit **78** through cooler **82** wherein the water vapor is condensed and into liquid vapor separator **84.** Water is removed from the lower region of liquid vapor separator **84** via valve **83** and conduit **86** and passed to separator **62.** The gaseous products from liquid vapor separator **84** are passed through conduit **74** via pump **92,** valve **94** into gaseous product separation and recovery units **90.**

Intermittently, during the operation, valve **36** can be opened to pass further amounts of the feed slurry into coal converter **10.** Furthermore, when desired, valve **50** is closed while valves **60** and **64** are opened to allow liquid slurry to pass from conduit **34** into conduit **56** to liquid solids separator **62** wherein solids are removed via conduit **66** and water is passed back to recycle conduit **34** via conduit **58.**

In accordance with a further embodiment of the subject invention, the pyrophoric mixture need not be utilized in the coal conversion process. In this instance, electrical power from leads **24** and **26** is utilized to strike and maintain an arc between cathode **20** and anode **22.** Next, particulate coal is supplied to water flowing through conduit **28** via solids feeder unit **44** and passed to liquid inlet **12** via pump **46** and valve **36.** The coal particles can comprise any desired concentration of the aqueous slurry such that when admixed with the recycled aqueous fluid flowing from leg **34***a* into conduit **28,** the resulting mixture comprises from about 2 to about 60 volume percent solids. The resulting slurry of coal particles is passed through the electric arc which is formed between the electrodes and at least surface portions of the particles are instantaneously heated to a temperature of from about 700°F to about 2,000°F and converted to lower molecular weight products. The recovery of the products, both liquid and vaporous, is effected in the same manner such as described above.

When operating in accordance with another embodiment of this invention, the pyrophoric material can be supplied or admixed with the coal slurry, which is passed through an arc maintained between anode **22** and cathode **20.** This embodiment can be utilized when maximum heat input is desired to form a large quantity

of low molecular weight aliphatic hydrocarbons, carbon monoxide, and hydrogen, for example.

It is noted that while only one liquid inlet **12** and one cathode **20** and anode **22** are illustrated in the drawing, it is to be understood that liquid inlet **12** can comprise any configuration designed to deliver the aqueous-coal slurry between any desired number of electrode pairs, whether operating in the electrolysis mode, described in connection with the above-described one embodiment or whether operating to produce an arc therebetween in accordance with the other above-described embodiment.

The exact temperature and flow rate conditions of the subject invention can be varied as desired to produce desired quantities of liquid and/or vaporous constituents from a particular coal feed product. It is generally only necessary to heat the surface of the coal particles passing through liquid inlet **12** to a temperature in the range of from about 700°F to about 2,000°F. Once the surface of the coal particles have been so heated, they will decompose to form lower molecular weight constituents. Since the decomposition products immediately pass within a cooled aqueous medium, the decomposition products will be quickly cooled or "quenched" and not undergo further degradation and-/or conversion. In addition, when hydrogen is present in the conversion zone, such as in the said first embodiment when coal converter **10** is operating in the electrolysis mode, the unsaturated hydrocarbon material will become hydrogenated. Thus, depending upon the kind of feed material utilized, the size of the electrode and the amount of voltage and amperage supplied thereto, as well as the presence of pyrophoric material in the mixture, the relative quantity of gaseous and vaporous products can be thereby controlled.

Furthermore, it is within the scope of this invention to pass the feed slurry from liquid inlet **12** through a series of electrodes. For example, a first electrode pair can be operated with an arc therebetween, and can be disposed in line with a second electrode pair operating in the electrolysis mode wherein large amounts of hydrogen are produced at the cathode. The passage through the initial electrodes will heat at least, the surface of the coal particles, to a temperature of between 700° and 2,000°F, while instantaneous passage through the second pair will contact the hot vaporous products with hydrogen, and hydrogenate the unsaturated portions thereof.

It is noted that the particle size of the coal which passes into mixing chamber **42** can vary from a powder, e.g., less than 325 mesh (U.S. Standard) to any convenient larger size such as about 5 mesh, (U.S. Standard). The Fe_3O_4 and aluminum are preferably pyrophoric powder size. It is also noted that as an alternate to aluminum, powdered bauxite can be utilized in the scope of the subject invention as the source for aluminum. The bauxite generally contains from about 30–75% of Al_2O_3. The action of the electrodes on the Al_2O_3 will convert it to Al which in turn will react with the Fe_3O_4 to form the pyrophoric mixture.

While this invention has been described in relation to its preferred embodiments, it is to be understood that various modifications thereof will be apparent to one skilled in the art upon reading this specification, and it is intended to cover such modifications as fall within the scope of the appended claims.

I claim:

1. A process of converting coal into liquid and vaporous hydrocarbons comprising:

a. passing an aqueous suspension of comminuted coal into a liquid aqueous medium contained within a reaction zone and through an arc maintained between spaced electrodes adjacent the lower portion thereof, said reaction zone having liquid and vapor recovery zones positioned adjacent the upper region thereof;

b. decomposing at least portions of said coal as it is passed through said spaced electrodes to form reaction products comprising hydrocarbon reaction products and passing said reaction products upwardly through said liquid aqueous medium, to said liquid and vapor recovery zones; and

c. recovering said hydrocarbon reaction products from said aqueous medium.

2. The process of claim **1** wherein a portion of said hydrocarbon reaction products liquefy as said portion is cooled and passed upwardly through said aqueous medium, and thereafter recovering the resulting liquefied product hydrocarbon from the top of said aqueous medium.

3. The process of claim **1** wherein normally gaseous reaction products are passed through said aqueous medium and recovered above the same.

4. The process of claim **1** wherein portions of said comminuted coal which are not decomposed when passed between said spaced electrodes are passed through said aqueous medium, and thereafter recirculated again through said spaced electrodes.

5. The process of claim **4** wherein a portion of said aqueous medium containing non decomposed comminuted coal is continuously passed from said reaction zone and through a cooling zone wherein it is cooled to a temperature well below the vaporization point of said aqueous medium and then a first portion thereof containing non decomposed comminuted coal is passed again between said spaced electrodes and a second portion thereof containing non decomposed comminuted coal is passed to said aqueous medium in said reaction zone at a point above said spaced electrodes.

6. The process of claim **5** wherein said first and second portions are about equal portions.

7. The process of claim **1** further comprising admixing reactive amounts of a pyrophoric mixture with said aqueous suspension of comminuted coal such that said pyrophoric mixture ignites and supplied energy for said decomposition when passed through said spaced electrodes.

8. The process of claim **7** wherein said phyrophoric mixture comprises Fe_3O_4 and aluminum.

9. A process of converting coal to lower molecular weight hydrocarbons comprising:

a. suspending coal particles within an aqueous stream;

b. passing said aqueous stream containing said suspended coal particles into a liquid aqueous medium contained within a reaction zone and heating said coal particles between spaced electrodes as they are passed into said liquid aqueous medium to cause decomposition of at least a portion of said coal particles and form said lower molecular weight hydrocarbons;

c. passing said lower molecular weight hydrocarbons through said liquid aqueous medium; and

d. recovering said lower molecular weight hydrocarbons from said liquid aqueous medium.

10. The process of claim **9** wherein at least the surfaces of said coal particles are heated to a temperature above about 700°F. within said aqueous medium to cause said decomposition, and vaporization of water at points adjacent said heating, and wherein the aqueous medium surrounding said heating is maintained in the liquid state.

11. The process of claim **10** wherein at least the surfaces of said coal particles are heated to a temperature within the range of from about 700°F. to about 2,000°F.

12. The process of claim **9** further comprising forming hydrogen at one of said electrodes as said coal particles are heated to react said hydrogen with at least a portion of the decomposition products of said coal to form at least a portion of said lower molecular weight hydrocarbons.

13. The process of claim **9** wherein said spaced electrodes within said aqueous medium are operating in an electrolysis mode.

14. The process of claim **13** further comprising admixing reactive amounts of a pyrophoric mixture with said coal particles in said aqueous stream such that said pyrophoric mixture supplies energy for said decomposition when passed through said spaced electrodes.

15. The process of claim **14** wherein said pryophoric mixture comprises Fe_3O_4 and powdered aluminum metal.

16. The process of claim **14** wherein said pryophoric mixture comprises FeO_4 and bauxite, the bauxite being reduced between said spaced electrodes.

17. The process of claim **10** wherein said heating occurs by passing said coal particles through an arc between said spaced electrodes within said aqueous medium.

* * * * *

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,870,611 Dated March 11, 1975

Inventor(s) George W. Vestal

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 34, "coat" should be --coal--;
line 66, "repidly" should be --rapidly--.

Column 4, lines 10-11, "apparatus is formed shown" should be --apparatus as shown--;
line 21, "isformed" should be --is formed--.

Column 5, line 32, "formulation" should be --formation--;
line 47, "Vaporous" should be --vaporous--.

Column 6, line 14, "condition" should be --conditions--.

Column 8, line 49 (Claim 7), "supplied" should be --supplies--;
line 52 (Claim 8), "phyrophoric" should be --pyrophoric--.

Column 10, line 13, (Claim 16), "FeO_4" should be --Fe_3O_4--.

Signed and sealed this 17th day of June 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks