Sept. 21, 1937. R. B. STITZER 2,093,493

MAKING FUEL GAS

Filed Dec. 4, 1935 3 Sheets-Sheet 1

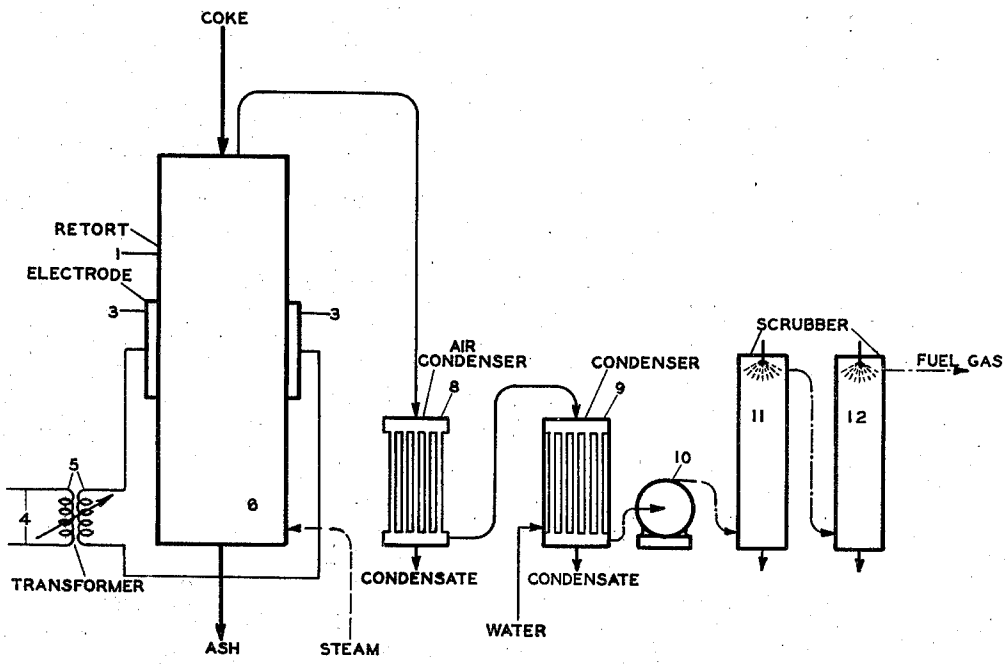


FIG. 1

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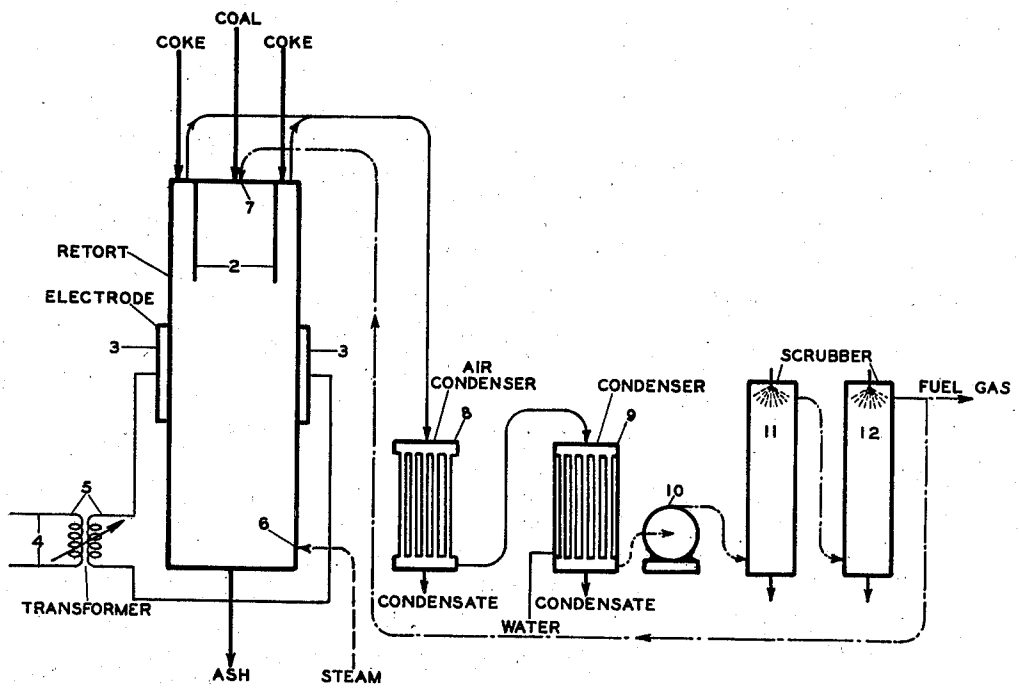


FIG. 2

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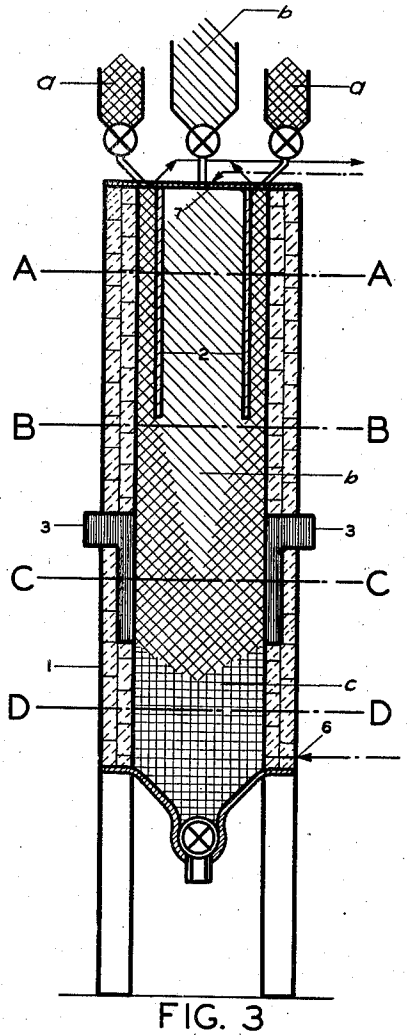


FIG. 3

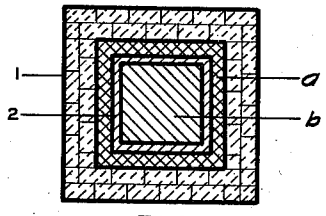


FIG. 4

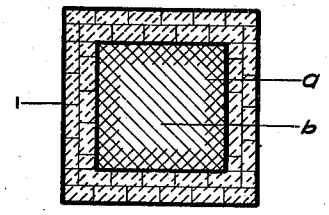


FIG. 5

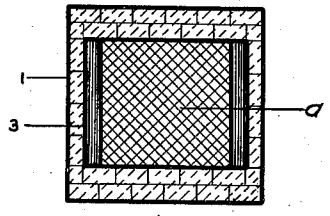


FIG. 6

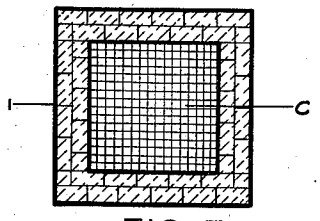


FIG. 7

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Patented Sept. 21, 1937 2,093,493

UNITED STATES PATENT OFFICE

2,093,493

MAKING FUEL GAS

Ralph B. Stitzer, Sheffield, Ala., assignor to Tennessee Valley Authority, Wilson Dam, Ala., a corporation

Application December 4, 1935, Serial No. 52,853

6 Claims. (Cl. 48—206)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

This application is made under the act of March 3, 1883, as amended by the Act of April 30, 1928, and the invention herein described, if patented, may be manufactured and used by or for the Government for governmental purposes without the payment to me of any royalty thereon.

This invention relates to a process for making fuel gas, particularly water gas, from solid carbonaceous materials.

One of the objects of this invention is to provide a continuous method and an efficient means for making fuel gas in which electrical current is used as a source of the heat required for the operation. Another object of this invention is to make a fuel gas of high calorific value, which is not diluted with inert gases such as nitrogen or carbon dioxide. Other objects of this invention include the economical utilization of off-peak electrical energy which is necessarily available in electrical distribution systems.

Solid carbonaceous materials have been carbonized to produce a relatively small quantity of fuel gas of high calorific value, with the production of a carbonaceous residue which must be further treated for a substantially complete conversion into fuel gas. Since the reaction between carbon and water vapor is endothermic, it is customary to alternately blast the carbonaceous fuel bed with air to raise the temperature of the bed to the proper reaction temperature, thereby making a producer gas of low calorific value, and contact the hot bed of carbonaceous fuel with steam to produce the water gas. The above principle is applied with many variations in operating details in various installations.

I have discovered a continuous process for making fuel gas by electrically heating a section of a column of solid carbonaceous material, by passing a supply of steam upwardly through the section of solid carbonaceous material which has been heated to a temperature sufficient to convert a substantial proportion of the steam into hydrogen and carbon monoxide. The solid carbonaceous material may be charged as solid carbonized material, as a solid carbonizable material, a mixture of the two, or the latter surrounded by an envelope of the former. The process of carbonizing a mixture of a solid carbonizable material and a solid carbonized material is disclosed in my co-pending application, Ser. No. 44,589, filed October 11, 1935, and the process and apparatus for carbonizing a solid carbonizable material surrounded by an envelope of solid carbonized material is disclosed in my co-pending application, Ser. No. 36,165, filed August 14, 1935.

In the accompanying drawings, which form a part of the specification, and wherein reference symbols refer to like parts whenever they occur,

Fig. 1 is a diagrammatic, vertical, sectional view of one form of apparatus for the embodiment of my process, in which coke is used as a source of the solid carbonaceous material.

Fig. 2 is a diagrammatic, vertical, sectional view of another form of apparatus for the embodiment of my process, in which both coal and coke are used as sources of the solid carbonaceous material.

Fig. 3 is a vertical, sectional view of the electrical carbonization retort in Fig. 2.

Fig. 4 is a plan view of the section A—A in Fig. 3,

Fig. 5 is a plan view of the section B—B in Fig. 3,

Fig. 6 is a plan view of the section C—C in Fig. 3, and

Fig. 7 is a plan view of the section D—D in Fig. 3.

In Fig. 1, coke is charged into the top of the vertical carbonization retort 1, and moves downwardly through the retort between a pair of electrodes or a plurality of electrodes, located in and flush with the opposite faces of the wall of the retort 1, and represented by electrodes 3. The coke charge between the electrodes 3, is heated to 2,000 to 2,400° C., the temperature for the conversion of a substantial proportion of steam into water gas, by the heat produced by the passage of an electrical current through the charge, which serves as a resistor between electrodes 3, the current to the electrodes being supplied from the electrical service lines 4, through the transformer 5. The hot coke which passes downwardly between electrodes 3, reacts with the steam which is admitted near the bottom of the retort at a plurality of points represented by inlet 6, and passes upwardly through the ash already formed and through the heated coke between the electrodes 3. The ash is withdrawn from the bottom of the retort. The water gas produced in the section between the electrodes 3, passes upwardly to heat the charge in the zone immediately above the electrodes and is withdrawn from near the top of the retort. This gaseous mixture of retort gas, together with entrained solid and liquid particles, usually resulting from the use of a charge which has not been completely carbonized, passes through the air condenser 8,

where the major portion of the tarry matter is removed, and through the condenser 9, in which the major portion of the volatile condensable matter in the retort gas is condensed by indirect cooling with water and separated from the gas. The retort gas, from which substantially all the condensable matter has been removed, passes into the inlet of the blower 10, which serves to maintain a substantially atmospheric pressure in the top of the retort 1, and the gas delivered by blower 10, is treated in scrubbers 11 and 12 to remove by-products, such as ammonia and other nitrogen compounds, and otherwise prepare the retort gas for use as a fuel gas, such as by the removal of hydrogen sulfide and other sulphur compounds.

In Fig. 2, coke is charged into the outer zone in the top of the vertical carbonization retort 1, which is between the inner wall of the retort and the gas impervious partition 2. Coal is charged into the inner zone in the top of retort 1, which is surrounded by partition 2. The charge of coal surrounded by the envelope of coke moves downwardly through the retort between a pair of electrodes or a plurality of electrodes, located in and flush with the opposite faces of the wall of the retort 1, and represented by electrodes 3. The coal in the charge between the electrodes 3, is carbonized largely from the heat produced by the passage of an electrical current through the carbon portion of the charge surrounding the coal portion of the charge, which serves as a resistor between electrodes 3, the current to the electrodes being supplied from the electrical service lines 4, through the transformer 5. The hot coke which passes downwardly between electrodes 3, reacts with the steam which is admitted near the bottom of the retort at a plurality of points represented by inlet 6, and passes upwardly through the ash already formed and through the heated coke between the electrodes 3. The ash is withdrawn from the bottom of the retort. The water gas produced in the section between the electrodes 3, passes upwardly to assist in the carbonization of the coal portion of the charge and to heat the charge in the zone immediately above the electrodes. A small proportion of an inert gas, comprised of fuel gas, is admitted through inlet 7, into the top of the inner zone in the top of the retort, into which the coal is charged and is passed downwardly in a sufficient volume to keep the uncarbonized coal in the inner zone substantially free from condensable carbonization products. The inert gas admitted at the top of the inner zone of the retort, the volatile carbonization products, and the water gas pass upwardly through the coke in the outer zone at the top of the retort and are withdrawn at the top of the outer zone. This gaseous mixture of retort gas, together with entrained solid and liquid particles, passes through the air condenser 8, where the major portion of the tarry matter is removed, and through the condenser 9, in which the major portion of the remaining volatile condensable material in the retort gas is condensed by indirect cooling with water and separated from the gas. The retort gas from which substantially all the condensable volatile matter has been removed passes into the inlet of the blower 10, which serves to maintain a substantially atmospheric pressure in the top of the outer zone of the retort 1, and the gas delivered by blower 10, is treated in scrubbers 11 and 12 to remove valuable by-products, such as ammonia and other nitrogen compounds, and otherwise prepare the retort gas for use as a fuel gas, such as by the removal of hydrogen sulfide and other sulfur compounds. A portion of this fuel gas is used to supply the inert gas admitted through inlet 7 into the top of the inner zone of the retort.

In Fig. 3, the coke *a*, charged into the outer zone in the top of retort 1, between the inner wall of the retort and partition 2, passes downwardly and surrounds the charge of coal *b*, which is fed into the top of the inner zone surrounded by partition 2. The coke *a*, and the coal *b*, continue to pass downwardly into the zone between the electrodes 3, in substantially the same relative position which they occupied on passing the bottom of partition 2. The coke *a*, serves as a resistor when it comes in contact with the electrodes 3, and the heat produced by the passage of the electrical current through the coke *a*, carbonizes the coal *b*, of the charge adjacent to it. The coal so carbonized in turn serves as a resistor and the carbonization proceeds. Since, however, the operation is a continuous one, the amount of uncarbonized coal *b*, left in the charge as it passes through the zone between the electrodes 3, is continually diminished until the coal *b*, has been carbonized in its entirety at the time, or shortly after it passes the elevation of the middle of the electrodes 3. The heating of the coke continues and its temperature is maintained sufficiently high for a substantial conversion of water vapor into water gas. The steam admitted through a plurality of inlets, represented by the inlet 6, as it passes upwardly through the retort, cools the ash *c*, which is produced and reacts with the highly heated coke *a*, substantially at the elevation of the bottom of the electrodes 3. The hot water gas which is formed serves to assist in the carbonization of the coal in the charge between and immediately above the electrodes 3, and to preheat the charge in the zone above the elevation of the top of the electrodes 3. The inert gas admitted through the inlet 7, in the top of the inner zone of the retort, passes downwardly and keeps the uncarbonized coal *b*, in the inner zone substantially free from condensable carbonization products. The inert gas admitted at the top of the inner zone of the retort, the volatile carbonization products, and the water gas pass upwardly through the coke *a*, into the outer zone in the top of the retort and are withdrawn from the top of this zone as the retort gas.

In Fig. 4, which is a plan view of a section near the top of retort 1, the coke portion of the charge *a*, in the outer zone is shown separated from the coal portion of the charge *b*, in the inner zone by partition 2.

In Fig. 5, which is a plan view of a section of retort 1, below the elevation of the bottom of the partition and above the elevation of the top of the electrodes, the coke portion of the charge *a*, is shown enveloping the coal portion of the charge *b*.

In Fig. 6, which is a plan view of a section of the retort 1, through the electrodes, *a* represents the coke portion of the charge and the carbonized portion of the charge, the two being practically indistinguishable at this point.

In Fig. 7, which is a plan view of the section of the retort 1, between the elevation between the bottom of the electrodes and the bottom of the retort, *c* represents the ash from the coal portion of the charge *b*, and the coke portion of the charge *a*, after substantially all of the carbon

has reacted with the water vapor to form the water gas.

It is evident that there are numerous factors which will influence conditions for the most satisfactory operation of my invention, the actual limits of which cannot be established except by a detailed study of each set of raw materials and the intermediate and finished products involved.

The term "solid carbonizable material" shall mean and include solid carbonaceous material, which has not been subjected to a carbonization process, and which may be heated to a sufficiently high superatmospheric temperature to remove the volatile products which it contains with the formation of a solid carbonized residue useful as a domestic or industrial fuel or otherwise in the arts. Examples of solid carbonaceous material include anthracite coal, non-coking and coking bituminous coals, and materials of recent vegetable origin, such as woods and nut shells. The term "carbonized material" shall mean and include any solid carbonaceous product resulting from the carbonization of a solid carbonizable material. Examples of carbonized material include low and high volatile cokes and charcoal.

The charge may consist of a solid carbonized material, such as coke, a mixture of a solid carbonizable material and a solid carbonized material, such as coal and coke, or a solid carbonizable material surrounded by an envelope of solid carbonized material.

The size of the solid carbonized material preferably is such that it will pass through a 2.5" mesh screen. The size of the solid carbonized material, when used in conjunction with solid carbonizable material, preferably is such that it will pass through a 1" mesh. Screenings which otherwise have little use for other metallurgical purposes may be used for this purpose. Should these screenings contain an excess of very fine material, such as below a 2.5" mesh, a small proportion of this material could be incorporated with the carbonizable portion of the charge when this portion of the charge is a coking coal. The size of the solid carbonizable material used in conjunction with solid carbonized material preferably is such that this portion of the charge will pass through a 2.5" mesh screen.

When solid carbonized material is used in conjunction with solid carbonizable material, the ratio by weight of the carbonized material to the carbonizable material may vary within considerable limits, depending upon the materials being processed. Using coke from bituminous coal and a coking coal of the sizes given above, the proportions may be varied from 10 to 30% and 90 to 70% by weight, respectively.

The vertical retort shown in the respective drawings has a square cross section but this cross section may be rectangular, hexagonal, octagonal, elliptical, round, or any other symmetrical cross section, so long as the electrodes may be so placed in the opposite faces and flush with the inner faces of the retort wall and operated in such a manner as to obtain complete carbonization of the carbonizable material which passes through the zone between the electrodes.

When solid carbonizable material is surrounded by an envelope of solid carbonized material, the partition in the top of the retort which forms the outer and inner zones in which the carbonized and carbonizable materials, respectively, are charged may be concentric to the inner wall of a retort of uniform cross section from top to bottom or the cross section of the upper section of the retort and the partition within may be circular regardless of the nature of the cross section of the zone above and between the electrodes. The partition forming the outer and inner zones extends from the top of the retort to an elevation located above the elevation of the top of the electrodes, preferably to an elevation located above the top of the electrodes equal to the distance between the electrodes, but may vary within a reasonable range, depending upon the nature of the carbonizable material charged and the volume of inert gas per unit weight of charge passed downwardly through the charge in the inner zone.

The electrodes may be a pair, or a plurality of electrodes, located in and flush with opposite faces of the retort. The power supplied to the electrodes may be single phase or three phase alternating current or direct current obtained from a standard power circuit. When alternating current is used, the transformer required is preferably a variable transformer in order to permit flexibility in operation, due to such important factors as a change in the quality of the charge and the charging rate.

The amount of steam admitted into the bottom of the retort will vary considerably, depending upon the temperature of the reaction zone for the water gas formation, the nature of the charge, and the amount of carbon in the residue withdrawn from the retort. With a 90% conversion of the steam to water gas, approximately 1.33 pounds of steam are required for each pound of coke and approximately one pound of steam is required for each pound of coal charged.

The water gas reaction is so slow below 1650° F. as to be practically nonexistent. At temperatures above 1650° F., however, the reaction is relatively fast, so that there is a rapid decrease in the amount of undecomposed water in equivalent mixtures at higher temperatures, particularly above 1800° F. It has been found preferable to produce the water gas by the invention disclosed, with the high temperature zone between the electrodes maintained at 1900 to 2500° F. In some instances, the decomposition of the water vapor seems to be in excess of that ordinarily expected for the apparent temperature of the high temperature zone. This may be partially accounted for by the fact that there are innumerable small arcs formed at the points of contact in the coke resistor.

The carbon in the coke used or produced may be substantially completely converted into water gas with only the ash contained in the charge remaining; or, for purposes of more convenient operation, a small proportion of carbon may be left in the ash. Ashes which fuse in the range of 1900° F. to 2200° F. are considered low fusing; those in the range of 2200° F. to 2600° F. are considered as middle fusing; and those in the range of 2600° F. to 3100° F. are considered as non-fusing. In general, the low fusing point ashes cause trouble through clinkering, but several factors in addition to the ash fusing point affect the clinker formation. When solid carbonized material or solid carbonizable material which contains an ash which fuses above the approximate temperature of the high temperature zone between the electrodes, the ash may be withdrawn directly from the retort without particular difficulty. When the fusing point of the ash contained in the charge is below the temperature of the high temperature zone between the electrodes, it may be necessary to permit the residue to carry

a substantial proportion of carbon, to prevent the fusion of the entire residue at the operating temperature, or to provide supplemental means to facilitate the withdrawal of the ash, such as supplying an auxiliary hearth so that the ash may be withdrawn in a fused state.

When the solid carbonizable material is surrounded by an envelope of the solid carbonized material, the inert gas is admitted into the top of the inner zone of the retort through one, or a plurality of inlets, at such a rate as to keep the uncarbonized material in the inner zone substantially free from condensable products. This rate has been found to be approximately one to three cubic feet of inert gas per pound of carbonizable material in carbonizing a coking coal at the rate of 400 to 1000 pounds per square foot of retort cross section between the electrodes per hour. The inert gas admitted into the top of the inner zone of the retort may be derived from any source, so long as it is not substantially reactive at any stage of its contact with the carbonizable portion or carbonized portion of the charge, or so long as it does not contain any substantial proportion of material which is reactive at any stage of its contact with the portions of the charge and may include such materials as natural gas, producer gas, water gas, and fuel gas produced by this process. It is ordinarily preferred to use fuel gas produced by this process.

The retort gas, which comprises the water gas, or water gas and volatile carbonization products, depending upon the nature of the charge and the nature of the process, is withdrawn through a plurality of outlets at or near the top of the retort and is cooled stepwise to remove tarry matter and other condensable materials by such means as one or a plurality of air-cooled condensers and one or a plurality of water-cooled indirect condensers. In any case, only a portion of the treated gas from the retort is required to supply the inert gas which may be required in the process. The pressure of the gas leaving the retort is maintained at substantially atmospheric pressure by means of a blower in the condensing and scrubbing system, preferably between the two. At least a portion of the gas discharged from the blower is maintained at a sufficient pressure to be supplied to the top of the retort without additional compression when the use of the inert gas is required. Otherwise, the scrubbing system may be maintained under a pressure at least equal to that required to deliver the inert gas to the retort at the proper pressure.

The retort is built with a steel shell and standard brick construction with a refractory lining. The electrodes, preferably made of carbon block, are located in opposite faces and flush with the inner faces of the retort in a mid-section of the retort. Substantially gas-tight charging mechanisms, fitted into a gas-tight metal retort top, supply the carbonized material and the carbonizing material from their respective hoppers into the inner and outer zones, respectively, in the top of the retort.

The water reaction between carbon and water to form carbon monoxide and hydrogen is endothermic and requires approximately 71,000 B.t.u. per pound mol. of carbon used, which is equivalent to approximately 28.8 kw.-hr. per thousand cubic feet of a water gas. 30 to 35 kw.-hr. of electrical energy are required per thousand cubic feet of water gas produced, using a coke charge, with the same amount of energy required, in addition to the energy required for the carbonization of the coal, using coal in the charge.

It will be seen, therefore, that this invention actually may be carried out by the modification of certain details without departing from its spirit or scope.

I claim:

1. Process of making fuel gas from a coking coal which comprises, charging coke continuously into an outer zone in the top of a vertical retort of square cross section, surrounding and gas-imperviously separated from an inner zone, with both zones open at the bottom and extending downwardly until they are adjacent to but above a heating zone in a substantially horizontal section of the retort; charging the coal continuously into the inner zone in the top of the retort; passing an electrical current, supplied to the sides of the heating zone, through the charge in the heating zone, the characteristics of the current being regulated so that the heat produced on passing thru the charge in the heating zone is sufficient to carbonize the coal and sufficient to heat the coke in the heating zone to the temperature of conversion of a substantial proportion of steam in contact with the coke into water gas; passing steam into the retort, near the bottom, countercurrent to the direction of flow of the charge to cool the coke below the heating zone, to react with the coke in the heating zone and to heat the coal and coke above the heating zone with the gaseous products formed; passing an inert gas into the top of the inner zone, withdrawing the retort gas, comprising the inert gas admitted into the top of the inner zone, the volatilized products of the carbonization and the water gas formed by the reaction between the steam and the coke, from the top of the outer zone at the top of the retort; separating condensable materials from the vapors so withdrawn to yield a fuel gas; and withdrawing the ash continuously from the bottom of the retort.

2. Process of making fuel gas from a carbonizable material which comprises charging carbonized material continuously into an outer zone in the top of a vertical retort, surrounding and gas-imperviously separated from an inner zone, with both zones open at the bottom and extending downwardly until they are adjacent to but above a heating zone in a substantially horizontal section of the retort; charging the carbonizable material continuously into the inner zone in the top of the retort; passing an electrical current, supplied to the sides of the heating zone, through the charge in the heating zone, the characteristics of the current being regulated so that the heat produced on passing through the charge in the heating zone is sufficient to carbonize the carbonizable material and sufficient to heat the carbonized material in the heating zone to the temperature of conversion of a substantial proportion of steam in contact with the carbonized material into water gas; passing steam into the retort, near the bottom, countercurrent to the direction of flow of the charge to cool the carbonized material below the heating zone, to react with the carbonized material in the heating zone and to heat the carbonizable material and carbonized material above the heating zone with the gaseous products formed; passing an inert gas into the top of the inner zone; withdrawing the retort gas, comprising the inert gas admitted into the top of the inner zone, the volatilized products of the carbonization and the water gas formed by the reaction between the steam and the carbonized

material, from the top of the outer zone at the top of the retort; separating condensable materials from the vapors so withdrawn to yield a fuel gas; and withdrawing the ash continuously from the bottom of the retort.

3. Process of making fuel gas from a coking coal which comprises forming a column of coal surrounded by a column of coke above a heating zone in a substantially horizontal section of a vertical retort with the inner zone above the heating zone containing the coal and the outer zone above the heating zone containing the coke gas-imperviously separated from each other from the top of the retort to a location adjacent to the heating zone; passing an electrical current, supplied to the sides of the heating zone, through the charge in the heating zone, the characteristics of the current being regulated so that the heat produced on passing through the charge in the heating zone is sufficient to carbonize the coal and sufficient to heat the coke in the heating zone to the temperature of conversion of a substantial proportion of steam in contact with the coke into water gas; passing steam into the retort, near the bottom, countercurrent to the direction of flow of the charge to cool the coke below the heating zone, to react with the coke in the heating zone and to heat the coal and coke above the heating zone with the gaseous products formed; passing an inert gas into the top of the inner zone; withdrawing the retort gas, comprising the inert gas admitted into the top of the inner zone, the volatile carbonization products and the water gas formed by the reaction between the steam and the coke, from the top of the outer zone at the top of the retort.

4. Process of making fuel gas from a carbonizable material which comprises forming a column of carbonizable material surrounded by a column of carbonized material above a heating zone in a substantially horizontal section of a vertical retort with the inner zone above the heating zone containing the carbonizable material and the outer zone above the heating zone containing the carbonized material gas-imperviously separated from each other from the top of the retort to a location adjacent to the heating zone; passing an electrical current, supplied to the sides of the heating zone, through the charge in the heating zone, the characteristics of the current being regulated so that the heat produced on passing through the charge in the heating zone is sufficient to carbonize the carbonizable material and sufficient to heat the carbonized material in the heating zone to the temperature of conversion of a substantial proportion of steam in contact with the carbonized material into water gas; passing steam into the retort, near the bottom, countercurrent to the direction of flow of the charge to cool the carbonized material below the heating zone, to react with the carbonized material in the heating zone and to heat the carbonizable material and carbonized material above the heating zone with the gaseous products formed; passing an inert gas into the top of the inner zone; withdrawing the retort gas, comprising the inert gas admitted into the top of the inner zone, the volatile carbonization products and the water gas formed by the reaction between the steam and the carbonized material, from the top of the outer zone at the top of the retort.

5. Process of making fuel gas from coking coal which comprises passing an electrical current, supplied to the sides of a heating zone in a substantially horizontal section of a retort, through a charge in the heating zone formed by surrounding a column of coal with coke above the heating zone, with the characteristics of the current being so regulated that the heat produced on passing through the charge in the heating zone is sufficient to carbonize the coal and sufficient to heat the coke in the heating zone to the temperature of conversion of a substantial proportion of steam in contact with the coke into water gas; passing steam upwardly through the heating zone; passing an inert gas downwardly through only the coal portion of the charge above the heating zone to a location adjacent to the heating zone; and withdrawing the retort gas, comprising the inert gas admitted into the top of the inner zone, the volatile carbonization products and the water gas formed by the reaction between the steam and the coke, from the top of the outer zone at the top of the retort.

6. Process of making fuel gas from a carbonizable material which comprises passing an electrical current, supplied to the sides of a heating zone in a substantially horizontal section of a retort, through a charge in the heating zone formed by surrounding a column of carbonizable material with carbonized material above the heating zone, with the characteristics of the current being so regulated that the heat produced on passing through the charge in the heating zone is sufficient to carbonize the carbonizable material and sufficient to heat the carbonized material in the heating zone to the temperature of conversion of a substantial proportion of steam in contact with the carbonized material into water gas; passing steam upwardly through the heating zone; passing an inert gas downwardly through only the carbonizable material portion of the charge above the heating zone to a location adjacent to the heating zone; and withdrawing the retort gas, comprising the inert gas admitted into the top of the inner zone, the volatile carbonization products and the water gas formed by the reaction between the steam and the carbonized material, from the top of the outer zone at the top of the retort.

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