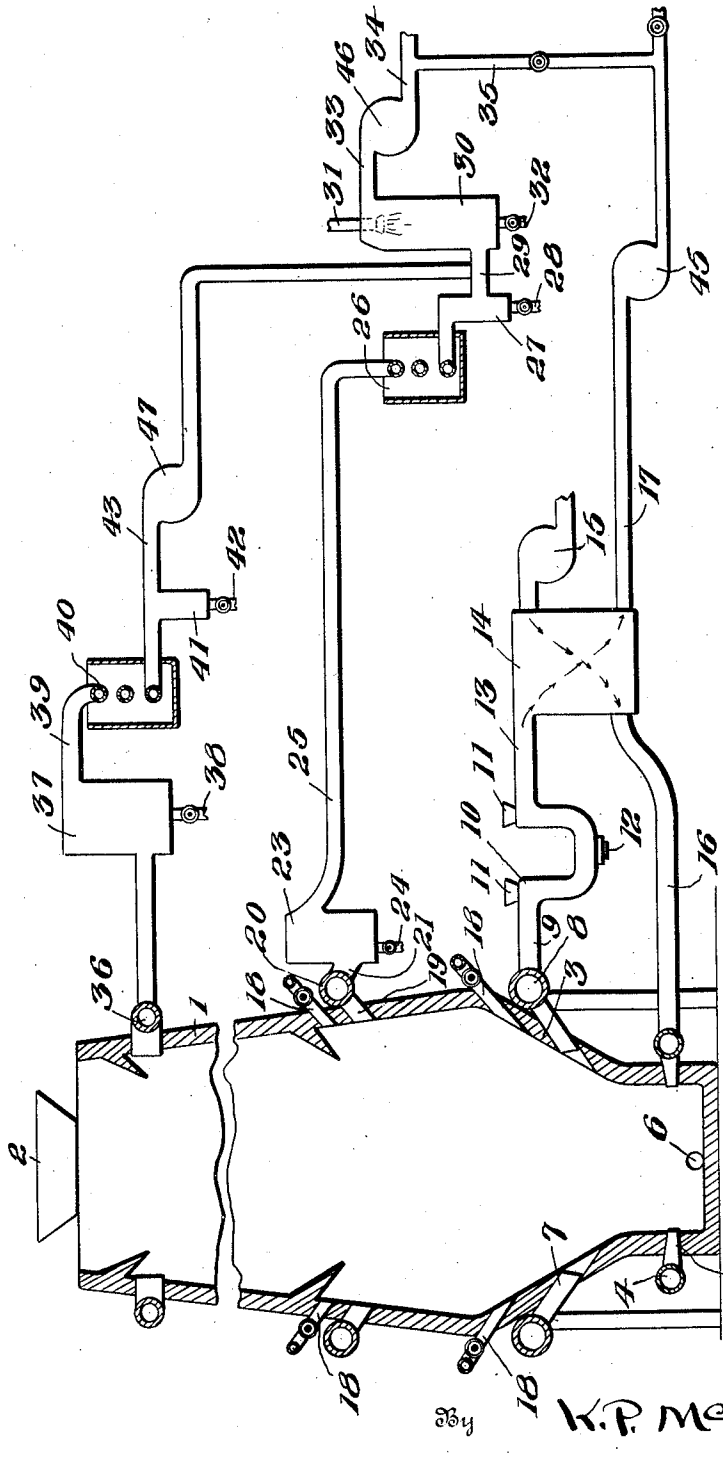
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K. P. McELROY

GASIFICATION OF COAL

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Inventor

By K. P. McElroy.

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UNITED STATES PATENT OFFICE.

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GASIFICATION OF COAL.

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To all whom it may concern:

Be it known that I, KARL P. McELROY, a citizen of the United States, residing at Washington, in the District of Columbia, have invented certain new and useful Improvements in the Gasification of Coal, of which the following is a specification.

This invention relates to the gasification of coal; and it comprises a method of utilizing bituminous coal and like fuels for the production of gas and by-products wherein the fuel is first methodically heated and distilled in the presence of a current of hot gases, thereby producing gas and oily products as well as an open textured residual carbon, and this carbon is then gasified by hot air under conditions giving a hot gas of high fuel value, a portion of this gas being used to furnish heat for the distilling operation and another portion to furnish heat to the air used; all as more fully hereinafter set forth and as claimed.

Under carefully regulated distillation conditions various oil shales may be used as a source of oils of the petroleum type, that is oils of the character known as paraffinoid; and the same kind of products may be obtained from various bituminous fuels, such as bituminous coal, cannel coal, lignites or brown coals, asphaltic coals and pitches, peat, and the like, if distillation be conducted at carefully regulated temperatures and in the presence of a current of steam or gas to sweep away the volatiles as fast as formed. With quick or forced heating of the fuel or any superheating of the produced vapors, these fuels also furnish oils but in less quantity and of quite another character, that of the oils of ordinary coal tar. For various reasons, however, it is difficult to utilize these bituminous fuels for oil making at a profit by the processes heretofore proposed. It is an object of the present invention to provide a method by which this may be done; production of oily products suitable for motor fuel, illumination, lubrication, and the like, being made an incident to, and a preparatory stage in, a high speed gasification of residual carbon. The two operations however although conducted as successive stages in the treatment of the same body of fuel and, usually, in the same apparatus, are separate and are independently regulated.

While other and more complicated types of apparatus may be employed, a simple shaft furnace suffices, distillation being performed in the upper part of the shaft and gasification in the base. In order to give independence in operation however a plurality of gas outlets are used, one being located in the gasification zone so that an adjusted fraction of the hot gas therein produced can be separately withdrawn without ascending through the descending body of coal. By so doing, conditions in the distillation zone, which is advantageously maintained a substantial distance above the gasification zone, are made readily controllable and independent of gasification conditions.

Most of the distillation of coal takes place between 300 and 400° C. although it begins around 250° and continues more or less up to 500°, or thereabouts. Under the action of the heat there is a breaking down or dissociation of the coal, or of its constituents, with evolution of various hydrocarbon gases and vapors; these primary products in turn tending to break down or crack with formation of secondary products. In order therefore to obtain any large yield of primary products by distilling coal a careful adjustment of thermal and other conditions must be made. The temperature of the coal should be caused to rise progressively and gradually through the ranges mentioned, and particularly the 300–400 degree range; opportunity being given for the escape of the volatiles formed at one temperature stage before going to the next stage. Volatiles should be removed from the point of formation as quickly as possible and without exposure to higher temperatures than those at which they are formed. Any quick or abrupt heating of the coal disturbs the regularity of the distillation and leads to losses. With a descending column of coal traversed by a countercurrent of hot gases to act as a heating agent and as a carrier agent for sweeping forward vapors, these requirements can be met; it being possible to establish and maintain in such a column a comparatively long distilling zone with a gradual temperature gradient between the stated limits. In so doing the length and temperature gradient of the distilling zone are controlled by correlating the flow of hot gases into the bottom of the zone with a removal of a controlled amount of vapor-

laden gases at the top of the zone. Much or most of the hot gases are diverted out of contact with the coal. Merely enough hot gases are allowed to flow upward through the coal beyond the point of diversion to give the desired amount of preheating to downcoming fuel. Vapor-laden gases may be diverted in controlled amounts at a plurality of points, thereby establishing and maintaining a corresponding plurality of zones of adjusted temperature. The diverted gases and vapors are sent to condensing means.

The temperature at which the vapor-laden gases are removed is of great importance, not only as regards the character of the products formed but as regards the working of the apparatus. In large part the primary volatiles consist of vapors of high boiling oils and waxes; these vapors existing as such because of the high temperature and of the dilution with gases. With any lowering of temperature, such as is caused by contact with colder coal, oily and waxy bodies condense in the coal and travel downward with it, returning to the distillation zone where they are revaporized and cracked. In securing maximum yields of these high-boiling hydrocarbons it is therefore in general desirable to remove the gases and vapors at about 300° C. If removal be at, say 250° C., a larger yield of light oils is secured at the expense of the heavier oils condensed in the coal and ultimately cracked down.

In what I regard as the best embodiment of my invention I divert the main body of the vapor-laden gases at a temperature of about 300° C., sending the diverted materials to suitable condensers and scrubbers. The rest of the gases ascend upward, preheating the descending coal and depositing therein oils condensing from the gas at temperatures below 300°. These condensed oils pass downward and ultimately (save to the extent they may be cracked down) rejoin the major flow. A certain amount of distillation takes place above the 300° outlet. So far as this produces condensable hydrocarbons they go downward; so far as it produces gases and light oil vapors they go upward. I find it desirable, and particularly with moist coals to make the final diversion of the gas current at a temperature around 100° C. There may however advantageously in some cases be an intermediate diversion at say 250°.

With a diversion at 300° and another at 100°, the products recovered from the former contain large amounts of high boiling oils and waxes (lubricating oils and paraffin) as well as intermediate oils of the nature of kerosene and light oils, such as gasoline. With some coals there may also be various aromatic hydrocarbons, such as benzol; with others aromatics are not formed. The products diverted at 100° C., on cooling usually give water and gasoline; a further portion of gasoline being recoverable by compressing or scrubbing the residual gases. These gases are rich in heavy gaseous hydrocarbons.

If the primary diversion be at 250° C. in lieu of 300°, the proportion of gasoline and light oils is increased at the expense of heavy oils and waxes. Where recovery of very heavy hydrocarbons is desired, there may be a diversion at 400° in addition to, or instead of, the diversion at 300°.

The coal pasing downward beyond the distilling zone is usually of a loose open or porous texture quite different from that of ordinary coke. Coke is usually produced under conditions adapted to make it as dense as possible; these conditions including a high temperature which causes distilled volatiles to undergo a secondary decomposition with deposition of carbon in the coke pores. In the present invention it is the purpose to avoid this secondary decomposition, vaporizing and removing the volatiles and making an open texture, highly porous carbon which will gasify rapidly with hot air in the gasification zone. The more completely volatiles are distilled off and removed, the quicker the carbon will gasify.

In ordinary gas producer operation the temperatures are rarely allowed to rise above 800° or 900° C. in the hottest zones, endothermics (steam or products of combustion) being usually admixed with the blast in order to aid in keeping the temperature down. This is for a number of reasons, one being to avoid mechanical difficulties with clinkered or sintered ash, and another being to produce somewhat more gas at the expense of the heat disappearing. Low temperature operation is however slow, so that a given apparatus does not turn out much gas per hour; and, furthermore, the gas is of relatively poor quality, containing considerable proportions of carbon dioxid. At all temperatures below about 1000° C., gas produced by blowing carbon with air must, because of certain equilibrum relations, have a relatively large ratio of CO_2 to CO.

The gasification in the base of the descending column of fuel may be done under ordinary gas producer conditions with the production from fired carbon of the ordinary type of producer gas; the only differences then being that a portion of gas is taken off directly from the hot zone and that gasification, because of the peculiar type of carbon, is more rapid. But I find it much better to operate at a much higher range of temperature; one sufficient to slag the ash constituents of the fuel, a little lime or limestone being added to the charge to aid in this. Ordinary lime-alumina-silica slags require a temperature of 1300°to 1400° C. At this high temperature gasification of carbon

blown with hot air is very much more rapid; a comparatively small apparatus giving as much gas as a battery of producers run in the usual way. In addition to getting high volumes of gas I also make a richer gas; one substantially free of carbon dioxid. The gas is very hot and some of its sensible heat may be transferred to the air.

As so far described, the operation of the lowermost gasification zone is that of a producer operating at high speed because of the open textured carbon supplied it and because of the high temperature, a temperature sufficient to form a freely liquid slag, and giving a gas of the composition normal at temperatures above 1000° C., with about 33 per cent CO; all the oxygen of the air blast being converted into CO without persistence of CO_2, any CO_2 primarily formed reacting with carbon to form 2CO. Since however the partial oxidation or semi-combustion of carbon to CO by a hot air blast gives much more heat than is requisite to keep the fuel mass at the slagging temperature there is a tendency, in the absence of anything to take up the surplus heat or constitute a load, for the temperature to rise above this point; and this is not desirable for various reasons, one being difficulties with furnace linings. Therefore I advantageously use a substance reacting endothermically to control the temperature and prevent such a rise, thereby obtaining a somewhat richer gas at the expense of the surplus heat units.

As the endothermic reagent absorbing the heat units in excess of the amount necessary to keep the producer zone at the necessary slagging temperature, I can use steam; a little steam or water vapor being admixed with the inflow of hot air. This gives me a sharp temperature control in the producer zone and somewhat more gas at the expense of the heat. In so doing, however, the gases abstracted from the producer zone are still at the inconveniently high temperature of 1400° C. or thereabouts and it is desirable to cool them somewhat, say, to about 1000° C. before using the ordinary heat exchanging devices. As stated I desire to use sensible heat from the gas in heating my air blast.

As the endothermic substance in the hot zone of my apparatus I find it however more advantageous to employ sodium carbonate since this not only gives me more gas and richer gas but also affords sodium cyanid as a by-product. Potassium carbonate or other potassium compounds may be used. At the temperatures here contemplated in the presence of carbon and nitrogen, sodium carbonate loses all its oxygen to form CO and becomes converted into fumes or vapors of sodium cyanid passing forward with the hot gas.

The withdrawn hot gas is apt to carry more or less solid matter (dust) in addition to such fumes of cyanid as may be present, and for this reason and also because of its high heat, it is desirable to purify and cool it somewhat prior to handling it in the usual heat exchanging devices (checker work or recuperators). Both purposes may be accomplished by passing it through a bed of charcoal or coke containing more or less soda which cools the gas by the formation of cyanid and also enriches the gas to a concomitant extent by the production of more CO and withdrawal of nitrogen. Any cyanid fumes or vapor carried by the gas coming from the producer are withdrawn by the carbon, being adsorbed thereby. Vapors of cyanid at 1400° or thereabouts carry a large quantity of sensible heat and of latent heat of vaporization; and this heat is also utilized for formation of cyanid in the filter in addition to the sensible heat of the gas itself. The carbon filter also removes flying dust and the like and delivers a clean hot gas of reduced temperature, suitable for direct use in any ordinary type of heat interchanger. The carbon filters may be steamed out from time to time to convert the nitrogen of the contained cyanid into ammonia and reproduce alkali.

The ammonia formed in steaming can be collected in any of the usual ways and by any of the usual apparatus. The alkali remains in the carbon and the carbon may be used again as a filter and cooling or heat absorbing material until the proportion of carbon becomes too small. When it is thus impoverished, it may be charged into the producer.

Working in the described manner, a cooled clean producer gas free from tar may be obtained from the filter and heat interchanger, carrying about 40 per cent or more of CO, instead of the theoretical 33 per cent. It is suitable for engines, furnace firing, and the like. The richness of the distillation gas coming from the upper zones varies with the fuel and the circumstances, but after scrubbing and cooling to recover tar, oils and ammonia, it is ordinarily still rich in character. It may be mixed with the other gas or used separately for suitable purposes.

In the accompanying illustration I have shown, more or less diagrammatically, certain organizations of apparatus elements within my invention and adapted for use in the described process.

In this showing, which is a view in vertical section, certain parts being shown in elevation, element 1 is a shaft furnace or gas producer of masonry or other suitable material. Its walls may be watercooled where necessary. At its top it carries a hopper feed 2 through which may be supplied the coal which is to be distilled and gasified.

This coal is most advantageously one rich in volatiles and low in ash. With the coal I supply lime or limestone in the amount necessary to slag the ash. With low ash coals, an addition of performed slag in small amount is also desirable. Various potassiferous silicates, such as feldspar, glauconite, and the like, may be used. If the excess of the heat in the crucible or hearth is to be utilized by sodium carbonate as an endothermic agent, ordinary soda ash in the correct amount may be fed in with the coal, or recovered alkali from a later operation may be so supplied.

As shown the shaft has a bosh region 3, similar to that in a blast furnace, air bustle pipe 4 and tuyeres 5. It is also provided with slag outlet 6. Leading from the bosh region are outlet pipes 7 for hot gas. A continuous annular outlet may be provided. These elements are advantageously water cooled. They lead to hot gas chamber 8 which communicates through pipe 9 with carbon filter 10, containing charcoal or coke and soda or other alkali and adapted to collect cyanid condensed or absorbed from passing gases together with liquid cyanid formed from the soda and carbon by reaction with the nitrogen of the gas. In practice several of these filters may be used in alteration, but only one is shown. The filter has loading inlets 11 at the top and discharging manhole 12 at the bottom. It may be provided with steam connections and ammonia connections not shown. As shown, it is of U-shape, as this structure is advantageous for collecting molten cyanid draining down. Passing through the filter, the gas, now cleaned and somewhat cooled by the endothermic action of cyanid formation, passes through exit 13 to heat exchanger 14, shown diagrammatically. It may be a recuperator of a regenerator of any of the usual types. Air passes into the heat exchanger from fan 15 and goes thence through hot air conduit 16 to the air bustle pipe. Gas leaves the recuperator through pipe 17 to a suitable place of use. The ratio of air going through 16 to the gas leaving through 17 can be adjusted as may be desired. All the gas formed in the crucible or gasifying zone of the producer which is not withdrawn as described through outlets passes up through the downcoming fuel in the shaft, heating and carbonizing it and freeing it of volatiles in the manner described. Passing upward through the mass it mixes with and carries forward the distillation gas formed and the vapors produced. If desired, a little steam or atomized water may be added through inlets 18 at various points to aid in temperature control and in localization of distillation. The gas and the vapors carried thereby ascend through the fuel in the distillation zone and are in part discharged at 19 into a collecting bustle pipe 20, the discharge being at any temperature desired; usually between 250° and 300° C. As shown, from this bustle pipe gases and vapors pass through conduit 21 into tar trap and air cooled chamber 23, provided with liquid outlet 24 and gas outlet 25. The gas and vapors, somewhat cooled, next pass through water cooled condenser 26 provided with trap 27, having a liquid outlet 28 and a gas outlet 29. Condensed hydrocarbons and ammonia liquor are removed through 28. Uncondensed gases next pass through scrubber 30 at any usual type, provided with inlet 31 for scrubbing oil and outlet 32 for oil charged with condensed vapor scrubbed out of the gas. In this scrubber is recovered a certain proportion of volatile gasoline, benzol, and the like. The scrubbed gas passed out through outlet conduit 33 and thence by pipe 34 to a suitable place of use. Or it may be led down by pipe 35 to be admixed with gas from the gasifying zone.

Returning to the shaft, a minor flow of hot gases is allowed to pass upward, beyond the point of diversion of the major flow, through the fuel to preheat and dry it, this minor flow being diverted from contact with the coal, usually, at a temperature around 100° C. The diverted gas passes into collecting bustle pipe 36 and thence into air cooled chamber 37 provided with liquid outlet 38 and gas outlet 39. From the liquid outlet there usually discharges, in addition to water, more or less floating gasoline.

The residual gas next goes through water cooled coils 40. Any condensate in these coils is collected in trap 41 and discharged at 42. Uncondensed gas is sent to the scrubbing device previously described by means of conduit 43. Draft conditions throughout the system are adjusted by means of suitable suction and pressure fans. Suction fan 45 on the hot gas line 7 to 17 from the producer; fan 46 on the line 19 to 34 carrying the major flow of vapor laden gases and fan 47 on the minor vapor flow line 36 to 43 can be so operated in conjunction as to establish any desired ratio of flow in these three lines. The outlets 36, 19 and 7 mark the division of the producer roughly into three more or less overlapping zones of preheating, distilling and gasifying. As shown, the relative sizes of bustle pipes 8 and 20 permit of the withdrawal through 8 of a major proportion of the gases formed in the gasifying zone.

Instead of using charcoal or other form of carbon in the filter 10 for the hot gas from the gasifying zone, any other suitable absorbing material may be used capable of withstanding the action of alkali; such as burnt dolomite. In lieu of using scrubbing oil for removing gasoline and vapors of

volatile hydrocarbons, ordinary types of absorbent filters containing charcoal, silica gels, and the like, may be employed; but I regard the use of a high boiling scrubbing oil as more desirable. Where the gases and vapors are withdrawn from the coal at a relatively high temperature and where the amount of carrier gas is not very great, the condensed high boiling oils and waxes may then scrub the gas sufficiently themselves abstracting a sufficient amount of gasoline and benzol. But ordinarily it is an economical procedure to scrub the absorbed residual gasoline out of the vapors by a special treatment.

Slagging temperatures and the high speed gasification incident thereto may be maintained in the gasifying zone without the use of hot air. In this event the heat exchanger shown and described need not be used. With cold air blast there is usually not much margin of heat available for the formation of cyanid vapors in the hearth, but some cyanid can form and in any event the sensible heat of the gas will produce cyanids in the carbon filter in the manner described. It is therefore advantageous, even in using air at the ordinary temperature to employ the carbon-alkali filter. The gases discharged at 800°–1000° C. are still as hot as is desirable for furnace firing and other uses for hot gas. In using cold air blast it is desirable to have the hot gas outlet from the producer at a rather higher level in the boshes than when hot air blast is used; or to use an auxiliary outlet taking out some gas at 400° to 500° C. in addition to the diversion outlets already described. As regards the actions in the hearth it is of course the same whether heat units are returned to the hearth in air or in carbonized residue. When hot air is used it may of course be heated in a stove or any other suitable device. But for the present purposes I regard the use of hot air heated by sensible heat of the gas delivered from the gasifying zone as to be on the whole the most advantageous.

In using a hot air blast and supplying alkalies with the coal, the supply of alkali is so correlated with the temperature of the blast and with the heat taken away from the hearth zone in hot gases as to prevent the hearth temperature rising much above the desired 1300°–1400°—that is, above the point at which slag will still form and run freely, observed tendencies to a rise of temperature being corrected by an increase in the proportion of alkali supplied with the fuel and to a drop in temperature by a diminution in the proportion of alkali supplied.

The oils and waxes collected in the various condensers are distilled and otherwise treated in the usual commercial ways to obtain the usual commercial products, gasoline, kerosene, lubricating oils, waxes, and the like. Sometimes phenols, cresols and the like, accompany the distillate; this being particularly the case with coals yielding benzol, toluol, and the like, as primary products. They may be extracted and recovered in the ways usual with coal tar oils. In a general way however the refining methods used with petroleum oils are better adapted to the present oils than are those used with coal tar oils. Such ammonia as accompanies the distillation gases may be recovered by the usual methods and apparatus, not shown.

What I claim is:—

1. The process of utilizing bituminous coal and the like fuels which comprises establishing and maintaining a descending column of such fuel containing alkali, blasting the base of the column with hot air at a sufficient temperature to maintain slag-forming temperatures in such base, diverting from such base a regulated portion of the hot gas formed, collecting cyanids therein contained, exchanging its heat with air to produce such hot air, allowing the rest of the gas to ascend through the column to form and volatilize hydrocarbons, drawing off gas and hydrocarbons at a plurality of points near the top of the column and recovering condensable hydrocarbons from the withdrawn gas.

2. In the utilization of bituminous coal and like fuels in slagging gas producers, the process which comprises distilling and carbonizing a descending column of such fuel and admixed flux by countercurrent contact with a regulated quantity of hot producer gas while withdrawing distillation products in vapor form from said column at points of adjusted temperatures, then gasifying the carbonized base of said column with hot air to make freely running slag and to generate said hot producer gas, while removing from said base at substantially the fuel temperature thereof such proportion of said producer gas as is not needed for said distillation.

3. The process of utilizing coal which comprises first drying and preheating the coal by gases having an initial temperature of about 300° C. passed through said coal and removed at a temperature of about 100° C., distilling and carbonizing the dried coal by an adjusted quantity of hot gases passed therethrough and removed from contact therewith at a temperature of about 300° C., said removed gases containing condensible hydrocarbons, and finally gasifying the residual carbon at a temperature in excess of 1000° C. by means of an air blast to produce hot rich gas of which said adjusted quantity only is used in said carbonizing and distilling.

4. In the operation of updraft gas pro-

ducers on bituminous coal, the process which comprises establishing and maintaining slag-melting temperatures in the base with the aid of preheated air, diverting a portion of the gases thereby produced, transferring heat from said gases to air to furnish said preheated air, passing an adjusted portion of said gases through heated coal to carbonize the same and furnish distillation products, diverting a portion of said gases, together with distillation products, from said coal when their temperature has fallen to about 300° C., and passing the undiverted portion of said residual gases through fresh coal to heat and dry the same.

5. In the operation of a gas producer establishing and maintaining a vertical column of distilling bituminous coal with a carbonized base, gasifying the said carbonized base at slag-melting temperatures with the aid of heated air, passing upward through said column such portion of the hot gases thereby produced as will flow freely therethrough while diverting the rest of the hot gases, diverting a portion of the upward passing gases when their temperature has fallen to a point in the neighborhood of 300° C., and passing the rest of the hot gases to contact with the coal above the latter point of diversion to heat and dry the coal.

6. In the utilization of bituminous fuel, the process which comprises establishing and maintaining a descending column of such fuel, gasifying the base of said column by an air blast to produce hot gas, diverting a controlled amount of said hot gas from contact with the fuel while permitting the rest to ascend through the column, diverting a portion of said ascending gas from contact with the fuel at a temperature in the neighborhood of 300° C., and diverting the residue of said gas from contact with the fuel at a lower temperature.

7. In the utilization of bituminous fuel, the process which comprises establishing and maintaining a descending column of such fuel, gasifying the base of said column by an air blast to produce hot gas, diverting a controlled amount of said hot gas from contact with the fuel while permitting the rest to ascend through the column, diverting a portion of said ascending gas from contact with the fuel at a temperature in the neighborhood of 300° C. and diverting the residue of said gas from contact at a temperature of about 100° C.

8. In the utilization of bituminous fuel, the process which comprises establishing and maintaining a descending column of such fuel with a carbonized base, gasifying said carbonized base with air to make clean producer gas, removing from said base the greater part of said gas so made while causing the rest of said gas to ascend in counter flow to said fuel to establish and maintain distilling zones of different temperatures therein, one of said zones being maintained under low temperature distillation conditions and removing adjusted portions of the ascending gas together with vapors carried thereby at different points along the height of said column to establish and maintain said distilling zones of adjusted differential temperatures.

9. In the utilization of bituminous fuel, the process which comprises establishing and maintaining a descending column of such fuel with a carbonized base, gasifying the said base with air to make clean producer gas, removing the greater part of the producer gas so formed while permitting the rest to ascend through said column to establish and maintain distillation conditions therein, removing a portion of the ascending gas, together with volatiles carried thereby, after a period of travel in contact with the fuel and before its temperature has fallen below a temperature range of 250° to 300° C., and permitting the rest of the gas to ascend through the coal above the point of removal.

10. In the utilization of bituminous fuel, the process which comprises establishing and maintaining a descending column of such fuel, gasifying its base with hot air under conditions affording temperatures sufficient to form freely running slag with ash constituents of such fuel, removing a controlled fraction of the hot gas thereby produced while permitting the rest to ascend through the fuel column, abstracting heat from the removed portion and transferring it to air for use in gasification, removing a controlled fraction of the ascending gases after a period of travel in contact with down coming fuel, said fraction being removed at a temperature sufficient to permit it to carry vapors of high boiling oils and removing the remaining fraction of the ascending gas after a further period of travel in contact with downcoming fuel.

11. In the utilization of bituminous fuel, the process which comprises distilling such fuel by a current of hot gases passing therethrough and removed at a temperature sufficient to permit them to carry forward vapors of high boiling oils and waxes, gasifying the residual open textured carbon by hot air under conditions affording slag melting temperatures, using a regulated proportion of the hot gas produced to furnish such current, removing the remaining proportion of such gas, cooling the removed hot gas somewhat by the aid of an endothermic chemical reaction, and further cooling said gas by air to aid in supplying said hot air.

12. In the utilization of bituminous fuel, the process which comprises distilling such fuel to remove primary volatiles, gasifying the residual hot open textured carbon by hot

air at a slag running temperature in the presence of an endothermic substance in sufficient amount to prevent the heat rising materially above such slag-running temperatures, removing hot gases at this temperature, further cooling the removed gas with the aid of an endothermic chemical reaction, and completing the cooling of the gas by air used to furnish said hot air.

13. In the utilization of bituminous fuel, the process which comprises admixing said fuel with slag forming fluxes and alkalies, distilling the fuel under regulated conditions to form and remove a large amount of distillation products and leave an open textured hot residual carbon, gasifying said residual carbon by a hot air blast at slag-forming temperatures to form a hot rich gas carrying cyanids, filtering and cooling said gas through a carbon filter containing alkali, and abstracting residual heat from the filtered gas, the abstracted heat being delivered to the air for the blast.

14. In the continuous operation with hot air of slagging gas producers provided with outlet for gas from the slagging zone and charged with fuel, fluxes and an alkali compound to serve as a gas forming endothermic reagent in the gasification zone, the process of controlling the temperature of the slagging zone which comprises so correlating the proportion of alkali compounds charged in the fuel with the temperature of the hot air as to maintain a temperature in said zone merely sufficient to deliver the slag in molten, freely running form, increasing the proportion of alkali with rise of the air temperature and decreasing alkali with fall of said temperature.

15. In the gasification of coal, the process which comprises establishing and maintaining a vertical column of distilling bituminous fuel with a carbonized base, blasting said base with hot air at a temperature at least sufficient to fuse and run ash components as slag, withdrawing a regulated portion of the hot gases from said base, filtering the withdrawn hot gases through carbon, and transferring the heat of the filtered gases to air in furnishing said hot air.

16. In the operation of an updraft gas producer blown with air and supplied with bituminous coal as a layer of substantial depth overlying the combustion zone, the process of increasing the speed of operation and regulating and enhancing draft through such layer which comprises removing a portion of the gas produced in such combustion zone directly from the combustion zone and removing another portion after passing through such layer with such adjustment of the ratio between the two portions of gas so removed as to maintain the fuel layer open and pervious and to deliver to the combustion zone an open-textured, rapidly gasifying carbonized carbon.

17. In the low temperature distillation in an updraft gas producer operated with air of a moving body of bituminous fuel by a countercurrent of a limited quantity of hot gases passed therethrough, the process of controlling the composition of distillates obtained in successive zones thereof which comprises removing successive definite fractions of such gases together with distillates carried thereby at different points along their line of travel, and balancing the amount of gases passing through each such zone against the amount of gases and distillates so removed and these amounts against each other so as to establish and maintain definite temperature gradients in said successive zones.

18. In the high-speed complete gasification of bituminous coal the process which comprises gasifying such coal, by a hot air blast, gasification being at a sufficient temperature to form free running slag, removing a part of the hot gas directly from the gasification zone and transferring a portion of its heat to the air to produce said hot air blast while causing an adjusted portion of the hot gas to flow in countercurrent contact with incoming coal to heat and distill said coal and to convert it into an open textured rapidly gasifying carbonized carbon which reacts with said hot air blast.

19. In the utilization of bituminous coal, the process which comprises establishing and maintaining a descending column of such coal in a suitable shaft furnace operated as a gas producer, maintaining a temperature in the base sufficient to form a freely running slag with the aid of an air blast, removing some of the gas so produced from said base while permitting a regulated proportion of such gas to ascend through the downcoming coal, removing a portion of the ascending gases laden with vapors of primary distillation products while still at a temperature sufficient to carry substantial amounts of vapors of high-boiling hydrocarbons, and removing at a higher point the rest of the ascending gases together with substantial amounts of vapors of low-boiling primary distillation products.

20. In the operation of an updraft gas producer with air, the process of improving productive capacity which comprises establishing a column of descending fuel undergoing low temperature distillation with a carbonized base and a substantially separate zone in which the carbon of said base is completely gasified, preheating and distilling said fuel by ascending counterflow of an adjusted quantity of the products of said gasification, while diverting directly from said zone of gasification such proportion of

said gasification products as is not needed for said preheating, distillation and carbonizing, said proportion being a major part of said gasification products.

21. In the operation of an updraft gas producer with air, the process which comprises establishing and maintaining a substantially separate zone of gasification of carbon and preheating said carbon by an adjusted quantity of the products of said gasification, while diverting a major proportion of said products directy from the zone of gasification and transferring the heat of diverted gases to the air used in said carbon gasification.

22. In the utilization of bituminous fuel with the aid of updraft gas producers using endothermics and preheated air, the process which comprises establishing and maintaining a vertical column of distilling fuel with a carbonized base, said base including a separate zone of carbon gasification, preheating said carbon and supplying heat for carbonization by an adjusted flow of the products of said gasification in countercurrent to descending fuel, while diverting a substantial proportion of said products from said gasification zone and transferring the heat of said diverted gases to the air used in said gasification.

23. In the manufacture of clean tar free engine gas directly from bituminous fuel in a gas producer blown with air, the process which comprises establishing and maintaining a descending vertical column of fuel with a tar free carbonized base and the upper portions of said column undergoing low temperature carbonization by aid of heat carried in an adjusted quantity of gases produced in the complete gasification of the carbon of said carbonized base with air, while removing the remainder of said gases without contact with nor transfer of heat to the fuel undergoing carbonization, said remainder being a clean tar free producer gas, and said remainder constituting a major proportion of the gases produced from said air.

In testimony whereof, I affix my signature hereto.

K. P. McELROY.