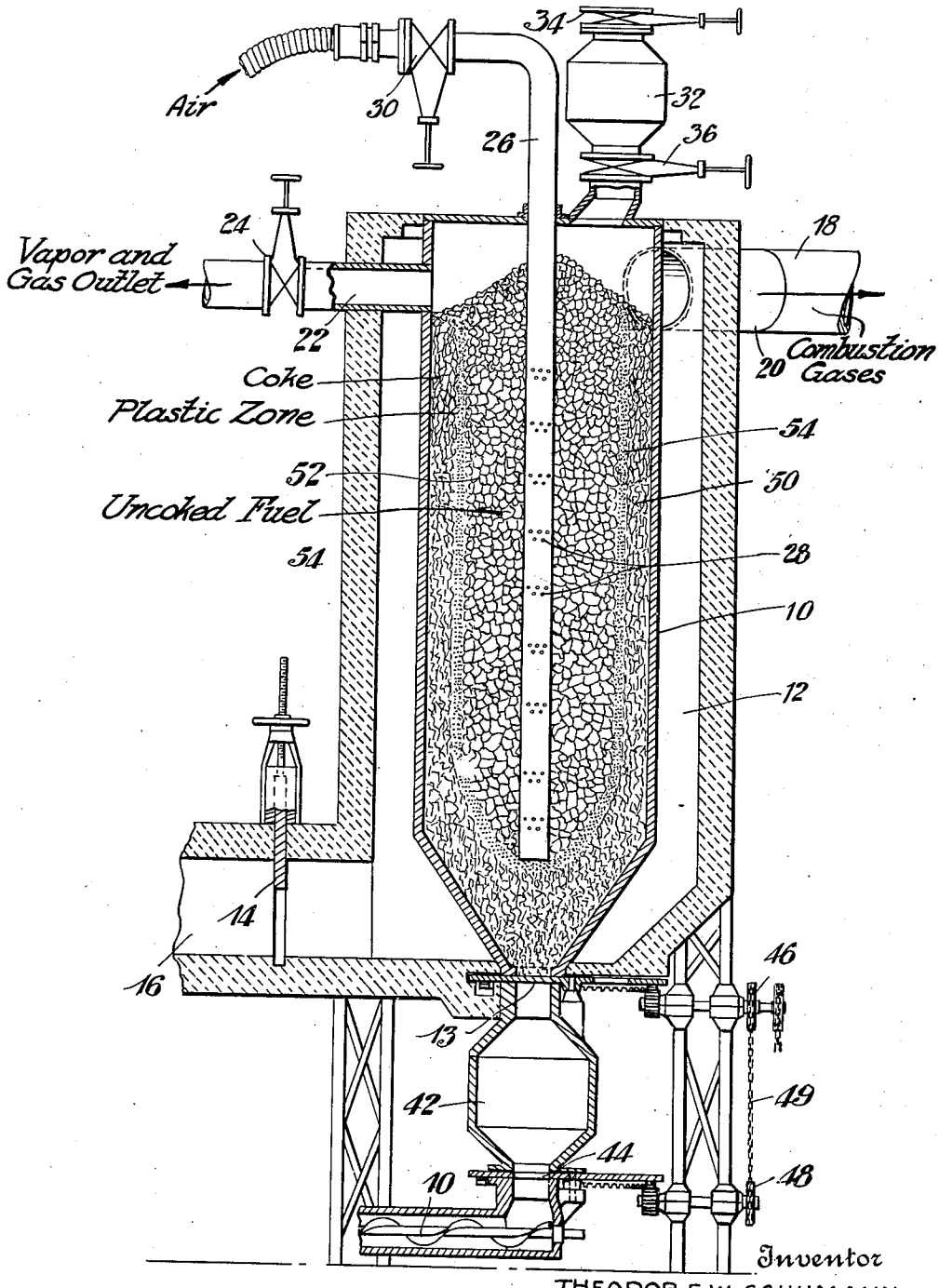
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PROCESS OF CARBONIZING COAL

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PROCESS OF CARBONIZING COAL

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The present invention relates to the art of carbonizing solid carbonaceous fuels and to the recovery of by-products therefrom. More specifically it relates to an improved method for rapidly carbonizing bituminous coal and the like in retorts such as those of the by-product coke-oven type in which the heat necessary for effecting carbonization is transmitted to the material being carbonized through the walls of the retort.

In the usual coking processes carried out in coke ovens such as those of the by-product type, the heat is applied to the outer walls of the retort, the heat after being conducted through the retort wall first contacting with that portion of the coal adjacent the said walls and thereafter slowly penetrating the charge by conduction, the rate of penetration decreasing rapidly as the distance between the material being coked and the source of heat increases. At a certain stage of this heat treatment the highly heated coal becomes soft and pasty and forms what is known as a "plastic layer", the latter being located along the boundary between the green or uncoked coal at the portion of the mass farthest removed from the source of heat and the already carbonized coal or coke adjacent to the walls of the retort. This "plastic layer", consisting essentially of semi-molten or heat-softened bituminous fuel and certain decomposition products thereof, is practically impervious to the passage of the gases and voltile products liberated from the coal during the coking process. Furthermore this "plastic layer" is an extremely poor conductor of heat, so that the flow of heat by conduction therethrough to the green coal from the heated walls of the retort is undesirably slow. This seriously interferes with and retards the carbonization process and limits the attendant production of coke, gas, and other products of the coking reaction, and restricts the capacity of the retort and makes necessary a very large expenditure for apparatus of sufficient size to produce coke and gas in commercial quantities.

Among the principal objects of my invention are: to provide in an improved manner for increasing the rate of carbonization of bituminous coal, oil shale and the like in retort apparatus employing heat transmitted by conduction through the retort walls; to provide for rapidly carbonizing coal and the like without materially affecting in an undesirable manner either the yields and character of tar and other volatile products of carbonization or the appearance and character of the coke or other solid product of carbonization; to provide for overcoming or minimizing the heat-insulating effect of the "plastic layer" that normally is formed during the carbonizing process and which gradually travels inwardly from the heated inner wall of the carbonizing retort toward the center of the coal charge under present known conditions of operation; and to provide, in a carbonizing process in which such a plastic layer of material is formed, for setting up and maintaining a predominent exothermic reaction (in place of the usual endothermic reaction) in that portion of the charge constituting the "plastic layer" and in the fuel adjacent the cool side thereof.

The invention in its broadest scope is based on the discovery that,—by introducing very limited regulated quantities of air, oxygen, or other suitable oxygen-containing fluid into a charge of coking coal in a retort at a point in the charge immediately adjacent to and on the coal side of the plastic layer where it is coolest, that is to say, at a point farthest removed from the source of heat, the limited amount of combustion thus set up or promoted at the cooler surface of the plastic layer which normally forms at the junction between the coked and the uncoked portions of the coal charge results in the development of a small amount of heat sufficient to make the reactions occurring in the plastic layer predominantly exothermic rather than endothermic, and by developing additional heat at the point where it is most needed greatly speeds up the coking reaction. The air finds its way from the cool side tc and even gradually into the plastic layer, and the heat there generated by the combustion which thereafter results has the effect of markedly accelerating the

movement of the plastic layer away from the source of primary heat supply. In a vertically disposed cylindrical retort, for example, the air is preferably introduced into the green coal in a plurality of small streams directed radially outward at a plurality of points along or near the major axis of the cylinder throughout its length, so as to effect an even distribution of the air through the coal. In a rectangular retort the air would preferably be introduced at points near the central longitudinal axis of the retort. The air, introduced into the coal in limited quantities, cannot pass through the plastic layer, but near the concave inner or cooler surface of the plastic layer the temperature is high enough to set up combustion between the air and small portions of the various volatile by-products resulting from the decomposition of the coal. The heat thus liberated adjacent the said inner surface of the plastic layer adds its effect to the heat being conducted to the outer surface of this layer from the external heating source and materially accelerates the rate of carbonization and the resultant movement of the said plastic layer toward the middle or cooler portion of the charge. In this manner a given charge of coal in an externally heated retort can be carbonized in a fraction of the time ordinarily required in processes employed prior to my invention wherein all the heat had to be conducted to and through the charge in one direction from the external walls of the retort. In my improved process the heat of the combustion set up by the small amount of added air is always liberated where it is most effective, that is at the inner surface of the plastic layer uniformly over substantially the whole area thereof, where the heat is utilized in carbonizing the coal and in driving off the volatile products simultaneously formed.

In the accompanying drawing, which shows a preferred form of apparatus for carrying out the process, the figure is a vertical cross section through a coking retort showing therein a charge at an intermediate stage in the coking process.

In the drawing, 10 is a closed vertically-disposed cylindrical coking chamber or retort set in a heating flue 12. The retort is provided with a frusto-conical or funnel shaped base portion normally closed by a valve 13. The flue 12 is provided with a suitable hot-valve or cut-off 14 and adapted to receive hot combustion gases in the usual manner from a furnace or the like (not shown) through a manifold flue 16. A discharge manifold flue 18 connects with the upper end of the flue 12 through the pipe 20, and leads to a stack, or it may lead to a heat-recovery device such as a waste heat boiler or the like, not shown. A gas outlet pipe 22 controlled by a suitable valve 24 connects the upper part of the retort 10 with a gas manifold (not shown), from which the gases and volatile products or carbonization may be conducted to storage after they have been suitably scrubbed and purified. A hollow, heat-resistant metal pipe 26 of relatively small diameter, (for example, of one inch or less) and having one end closed, is disposed so as to have its axis coincide with the axis of the cylindrical retort 10 and so as to have its closed end extend to a point adjacent to the bottom of the said retort, the other end projecting through and above the top of the retort 10 and leading to a suitable source of supply of air or other oxygen-containing fluid under pressure. The said pipe may if desired be constructed of a heat resistant alloy such as a chrome-nickel-iron alloy. The cylindrical wall of the pipe 26 within the retort 10 has its lower end closed and is provided at rather closely spaced intervals along the middle portion of that part of the pipe located within the retort with a plurality of relatively small capillary apertures 28, the arrangement preferably being such that a fluid under pressure may be introduced through the pipe into and uniformly distributed throughout the axial portion of a charge in said retort. The distance from the retort bottom to the lowest aperture in pipe 26 may be approximately the same as that between the retort side walls and the pipe 26. If desired, suitable means may be provided for varying the distance that the pipe 26 extends into the retort and for removing the said pipe from the retort as the coking proceeds or when it has been completed. A valve 30 in the line connecting the pipe 26 to the source of air or the like permits suitable adjustment of the rate of air flow therethrough. A suitable enclosing charging hopper 32 having the respective gas-tight inlet and outlet valves 34 and 36, is provided at the top of the retort 10 for use in charging into the latter the coal or other bituminous material to be coked. For discharging the contents of the retort after the carbonization thereof is completed a close screw conveyor or the like 40 has one end thereof connected with the lower or discharge end of an air-lock or sealing chamber 42. A valve 44 in the said lower end of the air-lock 42 controls the discharge of carbonized material therethrough. The upper end of the air-lock is connected to the bottom of the retort 10, the passageway between the two being controlled by the valve 13.

When the apparatus is to be employed in connection with a continuous carbonization process, the valves 13, 44, may be operatively associated by means of a pair of sprockets 46, 48, cooperating with a sprocket chain or the like 49. One of the

sprockets 46, 48, will then be driven from a suitable source of power by any of the well known power transmission devices (not shown). The valve arrangement is such that one of the said valves is open when the other valve is closed so as to effect the discharge of the contents of the retort without permitting access of air to the hot material within the retort. The plastic layer in the case of continuous operation in an apparatus of the type shown will tend to assume the general form of a cone having its apex in the lower end of the retort.

Where the process is to be carried out intermittently, the said valve 30 may if desired be equipped with an automatic timing device of well known type adapted for gradually cutting down and stopping the flow of air passing through the line 26 after the valve has been opened to initiate the air treatment of a charge of fuel being carbonized. This arrangement gradually reduces the air flow into the retort at a preselected rate corresponding to the reduction of the area included within the confines of the plastic zone as the carbonization proceeds.

In the drawing, 50 designates an annual layer of coke lying adjacent to the walls of the retort. A central body of uncoked or green coal 52 is shown surrounding the central pipe 26 in a cylindrical-shaped mass. Interposed between the latter and the annular layer of coked material 50 is a comparatively thin, relatively gas-impervious annular plastic layer 54 of coal and decomposition products thereof.

In carrying out the process forming a part of the subject-matter of this invention, according to a preferred embodiment thereof in connection with the apparatus described above, a charge of bituminous coal or the like, either cold or preheated to a desired degree is charged into the retort and heat is applied to the cylindrical side wall and bottom of the retort 10. After the heating has continued for a sufficient length of time to cause the definite formation of a plastic layer at or adjacent the retort walls, air, either cold or preheated, and under a relatively small pressure, as for example 2 lbs. per square inch, is forced radially outward and into the central portion of the charge of the coal through the aperatures in the pipe 26,—the rate of flow of the air being preferably maintained at a predetermined limited value, such as a rate of 2 cu. ft. of air per lb. of coal per hour, until carbonization of the charge has been completed. Both the charge and the central pipe 26 are preferably kept stationary during the process of coking, although it is within the scope of the invention to move the said pipe through the charge or to withdraw it entirely out of the retort 10 during the course of the carbonization in instances, for example, where for any cause the carbonization of the coal occurs much more rapidly in the lower portion of the coal charge than in the upper portion. Alternatively the air pipe 26 may be kept stationary and the body of coal may be passed slowly through the retort in a manner to maintain the relative position of the coal particles in the said body so as to provide a continuous coking process utilizing the substance of the present invention, i. e. the introduction of regulated small amounts of air into contact with the plastic layer of material formed during the carbonization at the side thereof remote from the source of primary coking heat, for the purpose of speeding up the coking process. In the case of a continuous carbonizing operation the coal is fed through the retort at such a rate that all portions of the air-introducing member 26 are on the cooler side of the plastic layer, that is, the side in contact with the green coal. Where the retort is heated both at the side walls and at the bottom thereof, as shown, the gradual withdrawal upward of the air-introducing member ensures that as the carbonization of the coal progresses, all of the air introduced into the mass will always be on the side of the plastic layer removed from the external heating agency.

To illustrate the effectiveness of my improved process, the following values are given showing the effect of the addition of air in the manner described upon the time required for coking a six inch layer of coal obtained from each of two different sources within a vertically disposed cylindrical retort:—

Kind of coal.	Rate of air introduction.	Time required for coking.
		Minutes
Pittsburgh	None	210
Same	2 cu. ft. per lb. of coal per hr.	111
Elkhorn	None	270
Same	2 cu. ft. per lb. of coal per hr.	132

As indicated above, the air pretreatment in the manner indicated reduces the time of carbonization of Pittsburgh coal approximately 47% and of Elkhorn coal approximately 51%.

To secure the best results it is desirable in carrying out the process to preheat the coal to temperatures substantially below 750° F.,—and preferably to temperatures within the range of from 500° to 700° F.—out of contact with air, before the coal is introduced into the retort and before the treatment with air has been initiated.

By varying within certain limits the amounts of air with which the coal is treated during coking, the time of carbonization is very appreciably modified. For example,

treatment of Pittsburgh coal in a retort of the type shown with ½ to 1½ cu. ft. of air per lb. of coal per hr. gives a carbonization time of 140 minutes, whereas the employment of 1 to 1¾ cu. ft. of air per lb. of this coal per hr. gives a carbonization time of 123 minutes; and treatment of this coal with two cu. ft. of air per lb. of coal per hour gives a carbonization time of 111 minutes. Experimental work indicates that there is an optimum rate of air flow or oxygen consumption which for Pittsburgh coal is approximately 2 cu. ft. of air per lb. of coal per hr. Results obtained using apparatus of the type shown indicate that the rate of oxygen consumption in the coking process decreases after the last mentioned rate has been attained, and increased air flow does not thereafter markedly decrease the time of carbonization although it does result in an increased combustion of the coke. The oxygen present in the air flowing through the coal reacts with certain constituents of the latter at a definite, approximately uniform, rate when in amounts from 1 to 2 cu. ft. of air per lb. of coal per hr., although when initially only ½ cu. ft. or less of air per lb. of coal per hr. is used the oxygen apparently does not so react. Where air in quantities of more than 2 cu. ft. per lb. of coal per hr. is employed the additional amount over that specified, while seemingly having little effect upon further accelerating the carbonization, apparently makes the reaction hard to control and gives visible signs of coke combustion. A rate of flow of 1 to 2 cu. ft. of air per pound of coal per hour may be otherwise stated as a flow of ⅕ to ⅖ cu. ft. of free oxygen equivalent per pound of coal per hour.

As the forward-moving molten coal zone or plastic layer progresses centerward and its surface exposed to the air flow decreases, experimental work indicates that a point is finally reached at which the said uncoked coal surface is insufficient to react with all of the oxygen supplied by the air, and the oxygen consumption falls off.

It may be stated generally that up to a certain maximum, the higher the initial retort temperature the more rapid the carbonization of the coal when employing air. For Pittsburgh coal this maximum temperature is in the neighborhood of 1420° F. At initial retort temperatures higher than this there is at first an increase in the rate of carbonization, but this preliminary gain is later lost prior to completion of the coking.

In carrying out the process with limited predetermined amounts of air, a very small amount of the total charge of coal is consumed in the combustion resulting therefrom, the amount of coal consumed being normally less than 4% of the total charge thereof. The amount of coal gas produced is somewhat greater when using air than when the same is not employed, but the B. T. U. value thereof is somewhat reduced. In one instance where Chilton coal was carbonized in a vertical retort in a layer 6″ in thickness, using an air flow of 2½ cu. ft. per lb. of coal per hr. a coke loss of 1.7%, a tar loss of 7.8% and a gas gain of 2.3% in volume, were observed. A substantial decrease in the sulphonation residue value of the tar from 28.7% to 12.7% where the air was employed, indicated a reduction in the amounts of the unsaturated compounds present in the tar due to the air treatment. Although the yield of tar is somewhat less where air is employed than where no air is employed, the specific gravity of the tar is little affected by the described air treatment, though it may in some cases be slightly raised thereby.

The invention further contemplates the use in the process of oxygen or of other oxygen-containing gases besides air—or of mixtures thereof,—or of an oxygen containing gas or gases mixed with non-oxygen containing gases such as various flue gases, oxygen-carbon dioxide mixtures, and the like which will react with the fuel under the conditions of carbonization and give off heat. The employment of a liquid which is capable of volatilizing at the temperature prevailing in the retort so as to liberate oxygen or an oxygen-containing gas within the coal layer, such as H_2O_2 solution, is also within the scope of the present invention.

It will be obvious to those skilled in the art that other designs of coking retorts may be employed instead of that here described and that horizontal or inclined retorts may be employed in place of those of the type shown. Any type or shape of by-product coke oven may be utilized for carrying out the essential features of the process when suitably modified in accordance with the above disclosure. The single pipe described above may be replaced by a number of perforated pipes spaced at intervals along the central plane of the retort. In all cases the retort is primarily heated externally and is provided with a suitable outlet for the escape of the volatile products formed during the carbonization process. It is an essential feature of this process that sufficient heat be transmitted to the coal being carbonized through the exterior wall or walls of the retort so as to cause formation of a plastic layer or zone within the material, and that thereafter a limited controlled combustion is set up at the face side of the plastic layer farthest removed from the external heating agency and in contact with the relatively cooler, green coal. This limited combustion area moves inwardly toward the center of the green coal charge and is directly ahead of the plastic layer as the latter progresses in that direction during the carbonization.

By the use of my process and apparatus as herein disclosed, I am able to effect the various purposes of my invention and to obtain a highly satisfactory grade of coke from bituminous material such as coal while simultaneously recovering the various valuable liquid and gaseous by-products normally formed in the coking process. The invention is susceptible of modification within the scope of the appended claims.

The invention having been thus described, what is claimed as new is:

1. The process of carbonizing solid bituminous fuel which comprises transferring the major portion of the heat required for carbonizing a body of the said fuel from an external source so as to coke the fuel progressively in the direction away from the source of heat and to form a plastic zone between the coke and the yet uncoked portion of the fuel, and supplying an oxygen-containing fluid in controlled amounts to the latter at points adjacent to the said plastic layer and only at the side thereof farthest from the said external source of heat.

2. The process as defined in claim 1 in which air is employed as the oxygen-containing fluid.

3. The process as defined in claim 1 in which the oxygen-containing fluid is employed in amounts ranging from 1/5th to 2/5th cu. ft. of free oxygen equivalent per pound of coal per hour of carbonizing time.

4. The process of carbonizing solid bituminous fuel comprising heating a body of fuel indirectly from an external source so as to progressively carbonize the fuel mass in a direction away from said source of heat and to form a plastic layer between the carbonized fuel and the yet uncarbonized fuel, and supplying and distributing an oxygen-containing fluid to the said plastic layer only on that side thereof adjacent the uncarbonized fuel.

5. The process as defined in claim 4 in which the fuel to be carbonized is preheated prior to the introduction thereinto of the oxygen-containing fluid.

6. The process of carbonizing solid bituminous fuel comprising heating a body of the said fuel from an external source so as to progressively carbonize the fuel mass in a direction away from said source of heat and to form a plastic layer between the coke and the yet uncarbonized portion of the fuel, and distributing a small amount of air to the said plastic layer only on that side thereof adjacent the uncarbonized fuel.

7. The process of carbonizing solid bituminous fuel comprising heating a body of the said fuel from an external source so as to progressively carbonize the fuel mass in a direction away from said source of heat and to form a plastic layer between the coke and the yet uncarbonized portion of the fuel, and supplying and distributing air at rates ranging from 1 to 2 cu. ft. of air per pound of the fuel per hour of carbonizing time to the said plastic layer only on that side thereof adjacent the uncarbonized fuel.

8. The process of carbonizing solid bituminous fuel which comprises heating a body of the fuel to a carbonizing temperature by heat conducted thereto through a highly heated surrounding diaphragm, progressively carbonizing the said body of fuel in a direction away from the said diaphragm while maintaining a moving plastic layer or zone between the carbonized portion of the fuel and the portion thereof yet uncarbonized, the said plastic layer moving in the direction away from the diaphragm, and contacting the forward surface only of the moving plastic layer with a small amount of a fluid capable of producing an exothermic reaction with the fuel at the said surface.

9. The process of carbonizing solid bituminous fuel, which comprises heating a confined body of the fuel to a carbonizing temperature in major part by heat conducted to the outer portion thereof through a highly-heated solid diaphragm, progressively carbonizing the said body of fuel in a direction away from the said diaphragm and toward the middle of the confined body so as gradually to reduce the volume of the uncarbonized remainder thereof, while maintaining a moving plastic layer or zone between the carbonized portion of the fuel and the portion thereof yet uncarbonized, continuously contacting the forward surface of the moving plastic layer with a combustion-supporting fluid and, as the heating continues, gradually reducing the amount of combustion-supporting fluid with which the fuel is contacted.

10. The process of carbonizing solid bituminous fuel, which comprises heating a confined body of the said fuel from an external source through a solid diaphragm so as progressively to carbonize the fuel in the body in a direction away from the solid diaphragm and to form a plastic layer between the resultant coke and the yet uncarbonized portion of the fuel, and uniformly distributing air alone within the said uncarbonized portion adjacent the forward surface of the moving plastic layer, the said air being employed in amounts of not more than 2 cu. ft. per lb. of fuel per hour of carbonizing time.

In testimony whereof I affix my signature.

THEODOR EBERHARDT WERNER SCHUMANN.