May 9, 1933.

S. W. PARR ET AL

PROCESS FOR COKING COAL

Filed Jan. 21, 1929

1,907,568

2 Sheets-Sheet 1

Fig. 1.

Fig. 3.

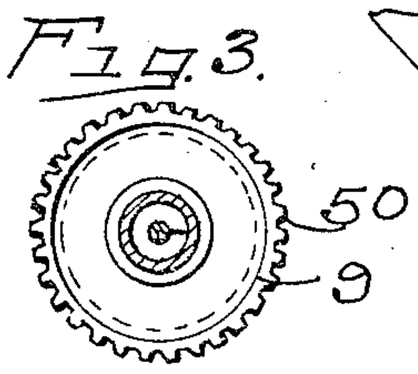

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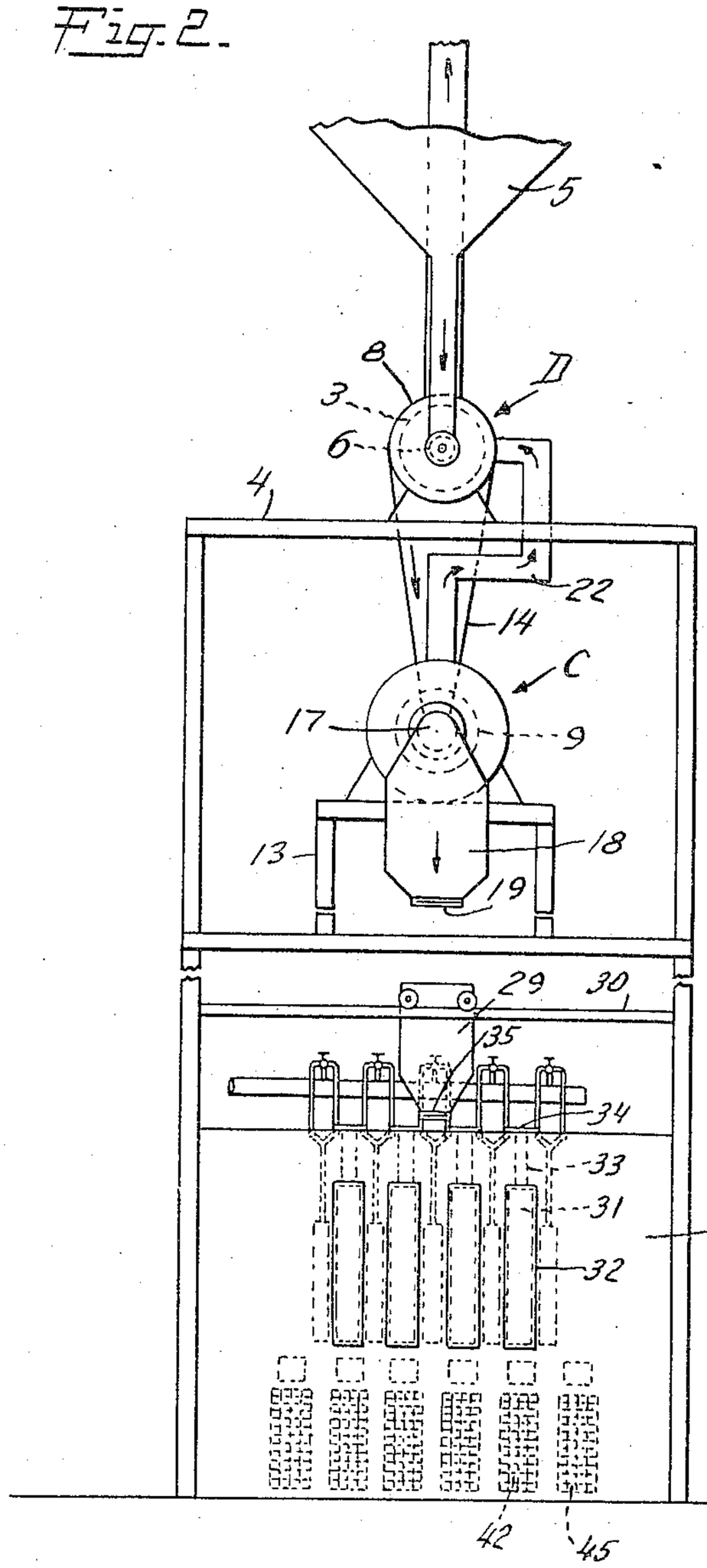
Fig. 2.



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Patented May 9, 1933 1,907,568

UNITED STATES PATENT OFFICE

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PROCESS FOR COKING COAL

Application filed January 21, 1929. Serial No. 333,814.

This invention relates to an improved process of coking coal, and more particularly concerns a coking process which results in the economical production of an improved and uniform quality of coke, tar and gas from various types of coal.

The primary object of most coking processes is the derivation of one product such as gas, coke or tar, from the coal treated, and according to ordinary by-product coking practice, the quality of the remaining or less important products is usually sacrificed to a certain extent. The cost of producing the desired primary product depends upon many factors such as the coking time, the heat required to carry out the coking operation, and the quantity and value of the secondary products obtained. Thus any improved coking process which results in a reduction in coking time and heat consumed while at the same time enhancing the quality and quantity of the by-products obtained, affects very substantial economy in the production of the desired primary product.

When coal is subjected to temperatures such that coke is ultimately produced, vapors and gases are driven off, the character of the volatile matter derived at any particular time being dependent upon the temperature of the fuel at that time and upon other factors such as the rate at which the coal is heated and the temperature of the coke oven walls or other surfaces or materials with which the evolved vapors come into contact. The hydrocarbon vapors evolved from coal at any given temperature are readily decomposed or cracked when subjected to temperatures higher than those at which they are evolved, and in ordinary by-product practice the valuable constituents thereof are largely lost or broken down into less valuable products during the coking process due to the prolonged contact of the evolved vapors with the hot walls of the coking ovens, or with masses of hot coke adjacent the oven walls.

According to ordinary by-product coking practice, raw coal is placed within an oven or retort and the walls thereof are heated until the entire coal charge is converted into coke. The coal in contact with the oven walls is first heated to a temperature at which it becomes plastic and is then converted into coke, and the plastic condition slowly progresses inwardly into the coal charge in a thin layer or envelope. The layer of coke adjacent the oven walls acts as an insulating barrier to the transmission of heat from these walls to the central portion of the fuel charge, thus appreciably delaying the coking operation and necessitating the use of excessively high oven wall temperatures. A portion of the hydrocarbon gases, which are largely evolved at or above the temperature of plasticity or critical temperature, condenses into tar on the inner face of the plastic layer or envelope on coming into contact with the relatively cold raw coal adjacent and within the plastic layer. This condensation of the hydrocarbons renders the plastic envelope comparatively impermeable to the passage of evolved gases, and a large proportion of the hydrocarbon vapors are accordingly forced to pass upward outside of the plastic layer through the hot coke and along the highly heated oven walls. This passage of the evolved vapors in contact with highly heated materials and surfaces within the oven, not only results in the above described undesirable cracking or decomposition of the hydrocarbons, but materially delays the coking process. Since the evolved vapors are largely excluded from the central mass of raw coal, the transmission of heat to this coal by convection through the vapors is prevented. The tar obtained in ordinary by-product practice comprises a mixture of high temperature and low temperature tar for the reason that some of the hydrocarbon vapors have been subjected to very high temperatures in the ovens, whereas a relatively small portion of the vapors have passed off through the raw coal at the center of the oven without being subjected to decomposing temperatures.

According to the present invention, it is proposed to utilize to advantage the exothermic heat available in the coal in order that the extraneous heat consumed as well as the coking time may be materially reduced. The improved process avoids the decomposition or cracking of the evolved vapors during the

coking operation and so enhances the values of the by-products derived. The process of the invention results in the production of an improved coke of uniform quality which is suitable for metallurgical or domestic uses, and further produces a rich gas and a tar of uniform composition containing valuable constituents. Illinois or other so-called "non-coking" coals may be treated by the process of the present invention, as well as the various coking coals.

Our improved method of treating the coal comprises first heating the coal substantially out of contact with the atmosphere and preferably, although not necessarily, with agitation, in such a manner that uniformly throughout, the average temperature of the coal is fairly close to but below the critical temperature thereof, that is, the temperature at which the coal first softens and becomes plastic. The temperature to which the coal is preheated is hereinafter more fully explained. The preheated coal is then confined in an oven and sufficient extraneous heat is supplied thereto to cause the coal temperature to increase quickly to and through the pasty stage and up to a final temperature of from 650 to 850° C., or higher. The preliminary heat treatment of the coal serves to condition it for the carbonization process which is to follow. During this preliminary heating, free moisture is driven off and certain reactions take place which result in the removal of deleterious oxygen and oxygen compounds such as H_2O and CO_2. The specific heat of gases such as H_2O and CO_2 is rather high, and the evolution and elimination thereof during the preheating stage therefore prevents the subsequent loss of an appreciable amount of heat through the evolution of these gases during the carbonization process. If the reactions just mentioned were allowed to occur simultaneously with the reactions of the carbonization stage, they would have the effect of weakening the binding material to such an extent that coke of an inferior quality would be produced.

Due to the preliminary heat treatment the portion of the fuel charge adjacent the oven walls is quickly carried up to the critical temperature and into the pasty stage, and the exothermic reactions which take place during the pasty stage result in the liberation of a considerable amount of heat which is transmitted to the adjacent portions of the fuel charge, thus causing the rapid autogenous progression of the pasty stage throughout the entire mass of the charge. The preliminary heat treatment of the coal promotes and makes possible this autogenous progression of the pasty stage for several reasons. Since the temperature of the coal is raised during the preheating process, to a value comparatively close to the critical temperature, the amount of heat required to bring the fuel to the critical temperature is comparatively small, and is well within the range of the available exothermic heat. Since certain gases having high values of specific heat such as H_2O and CO_2 have been eliminated during the preheating operation, the extraneous and exothermic heat available in the coking ovens is not carried away by these gases, and is directly available for raising the coal temperature to and above the critical value. Further, since the fuel charge is preheated throughout its mass, there is little or no condensation of the hydrocarbon vapors evolved from the coal adjacent the oven walls when these vapors come into contact with the central portions of the charge, and the formation of a more or less impermeable plastic envelope is thereby avoided. Thus the hydrocarbon vapors are not confined to the outer portions of the charge, but flow through the entire mass thereof, quickly carrying heat to the central portions of the charge and thereby accelerating the autogenous progression of the pasty stage.

The rapid progression of the pasty stage throughout the mass of coal charge prevents the formation of a concentrated and comparatively impermeable plastic envelope in the charge and the hydrocarbon vapors are evolved simultaneously throughout the entire fuel mass and escape through the entire charge rather than along the oven walls. The penetration of the evolved gases through the charge serves to aid in conducting heat to all portions thereof at a rapid rate, and the penetration of heat into the charge is further accelerated by the comparatively good heat conducting properties of the plastic coal. Since the coal charge is rapidly heated throughout to a temperature at which the evolution of gases begins, the gases are neither condensed nor decomposed or cracked during their passage through the fuel and out of the oven, and the tar and other products obtained are therefore of a superior quality. The rapid heating of the fuel charge through the plastic stage causes the shrinkage thereof much sooner than would be the case if raw coal were introduced directly to the ovens, and this shrinkage prevents the sticking of the coke and consequent difficulties in discharging the ovens.

The amount of heat available in the ovens for raising the coal temperature to and above the critical value and into the plastic zone is further increased by the fact that reactions of a secondary nature are largely avoided. It has been found that whereas primary reactions or decompositions taking place during the carbonization of coal are exothermic, secondary reactions are generally endothermic, resulting in the absorption of heat. Since the process of the present invention avoids such secondary reactions as the cracking of the evolved hydrocarbon vapors, the

heat ordinarily absorbed by these reactions is made available for raising the temperature of the fuel.

In accordance with the process of the present invention, the temperature to which the coal is preheated may vary between certain limits depending upon certain characteristics of the coal being treated, such as the critical temperature thereof, the amount of available exothermic heat liberated therein, and the temperature range of the plastic condition. In general, it may be stated that the present invention contemplates preheating the coal to a temperature such that the exothermic heat of the coal, when evolved, is capable of further raising the coal temperature from the preheating value to a temperature, preferably above the critical temperature, and high enough to ensure the autogenous progression of the exothermic reactions throughout the charge. As soon as the coal in contact with the oven walls reaches the temperature at which the exothermic reactions are initiated, the exothermic heat liberated thereby brings the adjacent coal to and above the temperature of exothermicity, and this action continues rapidly throughout the mass of the charge. The term exothermic heat, as employed herein, has reference to the excess of heat evolved by exothermic reactions over heat absorbed by endothermic reactions. The amount of exothermic heat liberated varies somewhat in different coals, but in general, the excess of exothermic heat over heat absorbed by endothermic reactions throughout the period when exothermic reactions are most in evidence has been found to be in the neighborhood of from 65 to 100 B. t. u. per pound of coal. The specific heat of coal at the temperatures under consideration is in the neighborhood of .34, and accordingly, 65 B. t. u. will raise the coal temperature approximately 106° C. and 100 B. t. u. will raise the coal temperature approximately 163° C. The exothermic reactions ordinarily take place at temperatures slightly above the critical temperature of the coal, and it is thus evident that a preheating temperature approximately 100 to 160° C. below the critical temperature may be sufficient to cause the above described autogenous progression of the exothermic reactions to the center of the coal charge.

The temperature ranges through which different types of coal remain plastic vary considerably. Thus this range is in the neighborhood of 80° C. for Illinois coals, 110° C. for eastern bituminous coals and 160° C. for semi-bituminous coals such as Pocahontas, it being understood that these temperature ranges include substantially all degrees of plasticity from the initial plastic condition to the final condition involving partial formation of coke structure. When coals having a relatively wide temperature range of plasticity are treated, it is feasible to preheat the coal to such a temperature that at least some of the particles of the charge are brought into the initial plastic condition before the charge is deposited into the coking oven. Since the swelling of the coal takes place at and above the temperature of initial plasticity, this procedure avoids the swelling of the charge in the oven at least to some extent. Even though the charge is preheated up to the temperature at or above that at which the coal first becomes plastic, substantially all of the exothermic heat is liberated in the ovens and it is possible to obtain coherent coke because the plastic condition persists long enough to permit the formation of a coherent mass in the ovens.

The above described heating of the coal to a temperature at or above the critical temperature thereof before the coking operation commences is set forth in our copending patent application, Serial No. 5,499 filed January 29, 1925.

Although the preheating temperature is preferably substantially uniform throughout the mass of the coal charge, it should be understood that certain of the finer particles of the coal may reach temperatures considerably higher than those attained by the coarser particles, and the preheating temperatures explained above are therefore the average temperatures of the coal charge at the termination of the preheating operation.

The preheating operation is preferably carried out in such a manner that the coal attains the desired temperature within a limited period of time. It has been found that if the time of preheating is unduly prolonged, certain reactions take place which prevent the elimination of the desired amount of deleterious oxygen and oxygen compounds. It is therefore preferred to preheat the coal to the desired temperature quickly, and the preheating time should be preferably less than two hours.

According to one embodiment of the invention, the preheating of the coal is carried out in two successive stages, the raw coal being first heated to a temperature equal to or slightly above the boiling point of water, and being subsequently heated, preferably in a separate container, to the desired final preheating temperature as explained above. The first or drying stage of the preheating treatment results in the removal of free moisture from the raw coal and raises the temperature thereof to a value at or slightly above the boiling point of water, preferably a temperature of 100° C., whereas the second or conditioning stage results in the above elimination of oxygen and oxygen compounds, and further increases the sensible heat of the coal. The drying operation is particularly advantageous when the coal has been washed previous to treatment and

by drying the coal in a separate container at a comparatively low temperature, the heating gases employed in the preheating operation can be very economically utilized.

The process of the present invention results in the production of a coke having desirable characteristics unobtainable in ordinary by-product practice. The coke obtained has an excessively high resistance to crushing strain, is clean and highly porous, and is further characterized by uniformity in structure and quality throughout the mass of the charge. This uniformity in the character of the coke is probably due to the above described autogenous progression of the exothermic reactions throughout the charge which results in the fuel charge being plastic and coherent throughout its mass. The coke as discharged from the ovens is characterized by the absence of the coking lines which are produced in ordinary by-product practice.

The improved apparatus employed to carry out the process of the invention includes suitable means for heating the coal out of contact with the atmosphere to the desired preliminary temperature. According to one embodiment of the invention, this means comprises two separate heating devices which may be termed a drier and a conditioner. The drier is arranged to supply sufficient heat to the raw coal to drive off free moisture and may conveniently comprise an inclined rotatable drum or cylinder through which the coal is tumbled and advanced while heat is supplied thereto. Since the temperatures attained in the drier are comparatively low, the coal therein may be heated by direct contact with suitable heating gases, these gases preferably passing through the drum in a direction opposite to that in which the coal progresses. The conditioner is preferably arranged to heat the coal rapidly, and to this end may conveniently comprise a closed cylinder or drum provided with suitable means for suplying a controllable amount of heat to the exterior surface thereof. In order that the coal may be agitated and so uniformly heated in the conditioning device, the cylinder may be rotated, or other means may be provided for tumbling and advancing the fuel therein. The coal in the conditioner is preferably heated indirectly, and the hot gases employed for this purpose are preferably conducted along the outer surface of the conditioning drum in the same direction as that in which the coal progresses therethrough. The heating gases thus employed may comprise waste flue gases from the ovens in which the coking process is completed, or a suitable fuel such as gas, oil or coal, may be burned to supply the required heat. The temperature of the gases employed to heat the conditioner is preferably variably adjustable by suitable means.

If desired, the drying and conditioning of the coal may be effected in a single operation, the raw coal being introduced directly to a drum or other suitable container and indirectly heated to the required preheating temperature therein. Although an externally heated container or preheating device is satisfactory for use in carrying out the process of the invention, it should be understood that this process is not limited to a device of this character and that the preheating operation may be carried out by passing a heated fluid through a mass of quiescent coal, or various other means may be employed for this purpose.

The apparatus for completing the coking process comprises a group or battery of coke ovens in which the preheated coal is deposited and in which the coking operation proper is completed. The ovens preferably comprise a unitary oven structure including adjacent oven chambers separated by walls containing heating flues. The oven structure is preferably formed of a suitable refractory material such as silica brick or fire-clay. The oven chambers may be of any suitable form, and may comprise horizontal ovens of the type commonly used in ordinary by-product coking practice. In the preferred form of the apparatus, the ovens comprise long narrow chambers having removable doors at their opposite ends, and provided with suitable apparatus for pushing the coke charge therefrom through one of these doors at the end of each coking operation. The ovens are preferably heated by burning a suitable fuel such as producer gas within combustion chambers in the oven structure, and conducting the hot gases through the oven flues. The air for supporting combustion in the combustion chambers is preferably preheated by the waste flue gases in suitable regenerators or recuperators.

Due to the above described evolution and flow of the hydrocarbon vapors throughout the mass of the coal charge within the oven, the oven wall temperatures employed during the coking operation may be comparatively high without causing undesirable cracking or decomposition of the hydrocarbons. Thus the oven wall temperatures may safely range from 750° to 1000° C. or even higher, the preferred wall temperature being in the neighborhood of 950° C. The final temperature of the coke charge may be varied according to the type of coke desired. It has been found that a superior quality of coke suitable for either domestic or metallurgical purposes can be made at final coke temperatures not exceeding 750° to 850° C., the volatile content of this coke not being in excess of 5%. If a lower volatile content is desired, the fuel charge may be allowed to remain in the oven for a longer period, without further material increase in the tempera-

ture of the charge. Such prolongation of the coking time, even at temperatures of 750 to 850° C., will have the effect of further reducing the volatile content and increasing the temperature of reactivity, similar to corresponding effects obtained by employing higher final coking temperatures but without producing the undesirable overcoking effects resulting from high final coking temperatures. The increase in the heating time produces a seasoning effect upon the coke without weakening the structure thereof. Since the oven walls are formed of refractory material, there is no danger of injury to the walls as a result of the high temperatures which they may attain, and thus the structural difficulties encountered when metal retorts or ovens are employed are avoided. It has been found that the heat stored in the relatively massive walls of the ovens flows into the coal charge rapidly and in sufficient amounts to complete the coking process within a comparatively short time, such as three and one-half to six hours.

When high oven wall temperatures are employed, a very thin crust or shell of coke may be formed adjacent the oven wall during the coking operation, and this shell may reduce the efficiency of heat transmissions to the coal to a certain extent. However, the high heat head established by the high wall temperature offsets the insulating effect of the coke shell and it is therefore possible to appreciably reduce the coking time by employing high temperatures, in spite of the formation of the coke shell. The formation of the coke shell does not in any way interfere with the above described autogenous progression of exothermic reactions to the center of the coal charge, for the reason that this progression is not dependent upon the accession of extraneous heat. Accordingly, even when extremely high oven wall temperatures are used, the coking takes place quite uniformly throughout the mass of the charge, and the coke produced is of a uniform quality throughout and does not contain the coking lines, that is, lines of division between various grades of coke, which are characteristic of ordinary by-product practice.

The ovens and the preheating apparatus are preferably located in close proximity and suitable means such as a lorry may be provided for carrying the preheated coal from the preheater to the ovens. The preheater preferably operates continuously and has a capacity sufficient to supply several oven chambers, the charges of preheated fuel being accumulated in the lorry. A small hopper or bin may be provided in which the preheated coal accumulates while the lorry is moved away from the preheater to charge an oven.

The various objects and advantages of the invention can best be understood by considering the accompanying drawings which show one embodiment of an improved apparatus by means of which the improved process of the invention may be performed. In the drawings;

Figure 1 is a sectional elevation of the improved apparatus for carrying out the process of the invention;

Fig. 2 is an end view of the apparatus shown in Fig. 1; and

Fig. 3 is an elevation, taken along line 3—3 of Fig. 1, and showing the driving gear of the preheating drum.

The embodiment of the preheating apparatus shown is of a type suitable for bringing the raw coal to the desired preheating temperature in two stages, and comprises generally a drier D and a conditioner C. The drier may conveniently comprise a drum or cylinder 3 suitably rotatably supported on the framework 4 and inclined toward the discharge end. A hopper 5 and a screw conveyor 6 are preferably provided for introducing raw coal to the inlet end of the drier cylinder 3, the power for operating the screw conveyor 6 and rotating the drum 3 being supplied by suitable means such as an electric motor (not shown). The gases for supplying heat to the coal in the drier are introduced at the discharge end of the cylinder 3 through a hood 7, and are drawn off through a similar hood 8 at the inlet end of the cylinder. The conditioner C preferably comprises a rotatable inclined drum or cylinder 9 mounted within a heating chamber 10 which may be heat insulated and is preferably provided with a plurality of baffles 11 for distributing the heating gases over the surfaces of the drum. The conditioner C is carried by the supports 12 and 13, the support 12 being vertically adjustable to vary the inclination of the drum and so regulate the advance of the coal therethrough. The dried coal is fed into the upper or inlet end of the conditioner drum 9 from a chute 14 communicating with the hood 7 of the drier D, through a power operated screw conveyor 15. A suitable source of power such as an electric motor may be employed to rotate the conditioner drum 9 and the screw conveyor 15. A plurality of blades 16, located within the discharge end of the conditioner drum 9, serve to lift the preheated coal and drop it into a chute 17 leading to a small hopper or bin 18. The lower end of the hopper 18 is controlled by a cut-off valve 19.

The inclined rotatable drum or cylinder 9 may be rotated by any suitable means, and to this end, the inlet end thereof is provided with a driving gear 50, as shown in Figs. 1 and 3.

The hot gases for heating the fuel in the conditioner C and the drier D may be supplied by any suitable means. In the disclosed embodiment, a suitable fuel such as

producer gas is burned in a furnace or combustion chamber 20, and the hot gases thus produced are conducted to the interior of the heating chamber 10 through the pipe 21. The waste heating gases from the conditioner are preferably supplied to the interior of the drier cylinder 3 through the pipe 22. The temperature of the heating gases supplied to the conditioner is controlled by regulating the supply of the fuel at the burner 23, and by introducing a variable amount of air to the furnace 20 or to the stream of combustion gases flowing therefrom. It is preferred to introduce the hot gases to the conditioner heating chamber 10 at the inlet end of the conditioner drum 9, and thus deliver heat from the hottest gases to the coolest portion of the coal charge in the conditioning drum. In this manner, the overheating of the coal in the conditioner is avoided. The waste gases from the conditioner heating chamber 10 are passed through the drier cylinder 3 from the discharge end to the inlet end thereof, in a direction opposite to that in which the coal progresses therethrough. By utilizing the heating gases to successively heat the coal in the conditioner C and the drier D, the heat in these gases is economically utilized, the temperature of the gases leaving the drier being little above that of the surrounding atmosphere. The rate of flow of the heating gases through the conditioner and the drier is controlled by the dampers 24, 25 and 26. If desired, the conditioner C and the drier D may be heated by waste flue gases from the coke ovens or from any other source, or a combination of waste gases and supplemental burner gases may be employed for this purpose. The waste gases may be supplied to the preheating apparatus through the pipe 27, the rate of flow thereof being controllable by the damper 28.

The preheated coal is preferably discharged from the hopper 18 into a lorry or car 29 mounted on the tracks 30 and adapted to supply the preheated coal to any one of a plurality of ovens 31. The lorry may serve as an accumulating bin for the preheated coal, the coal accumulating in the hopper 18 while the lorry is being moved away to charge one of the ovens. The lorry is preferably of such dimensions that it can carry enough preheated coal to fill at least one of the oven chambers 31.

The oven chambers 31 are preferably located within a unitary structure O formed of suitable refractory material such as silica brick or fire clay. In the disclosed embodiment the oven structure includes four oven chambers, but the number of these chambers may, of course, be varied to suit the requirements of the installation. The ovens in the disclosed construction are of the horizontal type, comprising narrow chambers of considerably greater length than height. The chambers 31 are provided with suitable removable doors 32 at their opposite ends through which the finished coke charge may be pushed by suitable apparatus. A plurality of charging ports 33 are provided in the upper wall of each oven chamber, these ports being normally closed by the caps or covers 34 and being disposed to align with the depending valve controlled discharge ports 35 of the lorry 29. The evolved hydrocarbon vapors are conducted from the ovens through suitable up-take pipes 36 and are conducted through apparatus for effecting the recovery of the valuable constituents thereof.

The oven chambers 31 may be heated in any convenient manner. The oven heating apparatus shown is of a type ordinarily employed in by-product coking practice, and since apparatus of this type is well known in the art, the structure thereof wi l only be briefly described herein. As shown in the drawings, the wall between each adjacent pair of oven chambers 31 is provided with two sets of flues 37 and 38, having combustion chambers 39 and 40 at the upper ends thereof respectively. A suitable fuel such as producer gas is first admitted through the passages 41 to the combustion chambers 39 at the upper ends of the flues 37, and heated air is supplied to these combustion chambers from a regenerator 42 through the passages 43 to support the combustion of the gas. The hot gases flow downwardly through the flues 37 upwardly through the adjacent flues 38 and finally pass downwardly through the passage 44 and through a regenerator 45 adjacent the regenerator 42, being carried therefrom to a stack through the tunnel 46. At suitable periods, the operation of the flues is reversed, fuel gas being admitted to the combustion chambers 40 of the alternate flues 38 and the waste flue gases passing out through the passages 43, the regenerator 42 and the tunnel 47. In this manner, during successive operating periods, the adjacent regenerators 42 and 45 alternately absorb heat from the waste flue gases and deliver heat to the air supplied to the combustion chambers, and the heat in the waste flue gases is thereby conserved.

In carrying out the improved process by means of the apparatus illustrated in the drawings, the raw coal is first delivered in crushed form to the cylinder 3 of the drier D through the conveyor 6. Within the drier, the raw coal is tumbled and advanced in direct contact with heating gases and is quickly raised to or slightly above the boiling point of water. In the drier, the free moisture in the raw coal is driven off, and the temperature of the coal is raised to a value preferably between 100 and 120° C. The dried coal passes through the chute 14 and the conveyor 15 to the drum 9 of the conditioner C, and is indirectly heated therein, out of contact with the atmosphere, to the re-

quired preheating temperature. As hereinbefore explained, the final temperature to which the coal is heated in the conditioner should be at least high enough so that the exothermic heat subsequently made available in the coal is sufficient of itself to heat the coal from this temperature to or above the temperature at which the exothermic reactions begin, thereby insuring the autogenous progression of exothermic reactions throughout a charge of this preheated coal during its subsequent treatment in the ovens. Since the coal is agitated by the rotation of the conditioner drum 9, it is heated substantially uniformly throughout and at a rapid rate. The preheating of the coal in the drier and the conditioner may be completed in a very short time, and should not consume more than two hours. The preheating conditions the coal by driving off water vapor, oxygen, oxygen compounds and other materials which should be removed before the coal is subjected to coking temperatures in order to cut down the coking time and improve the products obtained. As explained above, the preheated coal is accumulated in the lorry 29 and is subsequently discharged into the oven chambers 31, the walls of which have been previously preheated to a temperature between 750° and 1000° C., or even higher, this initial wall temperature preferably being in the neighborhood of 950° C.

The portion of the preheated coal charge which lies adjacent the oven walls is quickly raised by extraneous heat from these walls to a temperature above that at which exothermic reactions are initiated, and the heat liberated by these exothermic reactions raises the temperature of the adjacent portions of the coal charge to and above the point at which exothermic reactions take place therein. In this manner, the exothermic reactions progress rapidly and autogenously to the center of the fuel mass, and the entire charge is quickly brought to a plastic and coherent condition throughout. The progress of the plastic condition through the charge is accelerated by the evolved hydrocarbon gases which carry heat to the central portions of the charge as they flow upward to the oven. Since the hydrocarbon vapors are simultaneously evolved throughout the coal charge and are not confined by a plastic envelope to the outer portions thereof adjacent the hot oven walls, these vapors are withdrawn from the ovens without being subjected to cracking temperatures and substantially no heat is absorbed from the charge by secondary decompositions of this nature.

The coking operation proceeds until the desired coking temperature is obtained whereupon the doors 32 of the oven chamber are opened and the coke charge is pushed out by suitable means. A final coking temperature of from 750 to 850° C. has been found to result in the production of a good grade of coke for domestic or metallurgical purposes, the volatile content of the coke thus produced being not in excess of 5%. Due to the conditioning operation employed, the entire coking operation can be completed in from four to six hours. When coke of lower volatile content is desired, the coke charge is permitted to remain in the oven for a longer period, such prolongation of the coking time resulting in a reduction of the volatile content of the coke and an increase in the temperature of reactivity thereof, even though the final coking temperature is not materially increased. The process of the invention is thus quite flexible, it being possible to produce coke of any desired volatile content by simply varying the time period during which the charge remains in the oven. Although as explained above, coke of very low volatile content may be produced at low final temperatures, the process of the present invention is not limited to such temperatures and in certain cases the coking temperatures may reach values from 950 to 1000° C. or even higher. Regardless of the final coke temperatures attained, the process of the invention results in the above noted advantages such as the uniformity of the coke structure, the value and uniformity of the tar and gas produced, and the economy in heat and time consumed, these advantages being largely due to the manner in which the fuel is heated up to and through the plastic stage, and to the above described utilization of the exothermic heat available in the coal.

When the coal is preheated to a temperature at or slightly above the critical temperature of the coal, a certain amount of the swelling incident to the plastic stage takes place within the conditioner C, and the swelling of the charge in the oven chambers is thereby appreciably reduced.

From the foregoing description of the invention it will be apparent that by employing the preheating operation described, the coal may be coked in a very economical manner. Not only is the coking time appreciably reduced, but certain other disadvantages, formerly considered inevitable, in by-product practice, are largely eliminated. Thus the sticking of the coal charge in the oven is avoided, the evolved hydrocarbons are not cracked or decomposed in escaping from the ovens, and the coke produced is of a uniform and desirable character throughout the charge.

It is to be understood that the described process and apparatus may be varied without departing from the spirit of the invention which is not limited to the particular embodiments illustrated and described, but includes all such modifications thereof as fall within the scope of the appended claims. For example, while it is preferred to use the

type of preheating apparatus described, other devices by which coal can be uniformly heated to the desired preliminary temperatures may be employed.

We claim:

1. The process of coking coal which comprises heating the coal uniformly throughout and with agitation out of contact w th the atmosphere to a temperature below the minimum temperature at which exothermic reactions are initiated in the absence of air but high enough so that the exothermic heat available in the coal from exothermic reactions in the absence of air is sufficient to bring the coal from such temperature to at least a temperature at which exothermic reactions are initiated in the absence of air, depositing a charge of the preheated coal in an oven and supplying sufficient extraneous heat to the coal in the oven to bring at least a portion of said charge to the minimum temperature at which exothermic reactions are initiated in the absence of air and to coke the coal.

2. The process of coking coal which comprises heating the coal with agitation and uniformly throughout in an air excluding container to a temperature below the minimum temperature at which exothermic reactions are initiated in the absence of air but high enough so that the exothermic heat available in the coal from exothermic reactions in the absence of air is sufficient to bring the coal from such temperature to at least the minimum temperature at which exothermic reactions are initiated in the absence of air, depositing a charge of the preheated coal in an oven, and supplying sufficient extraneous heat to the coal in the oven to coke the coal.

3. The process of coking coal which comprises heating the coal uniformly throughout and with agitation in an air excluding container to a temperature below the minimum temperature at which exothermic reactions are initiated in the absence of air but high enough so that the exothermic heat available in the coal from exothermic reactions in the absence of air is sufficient to bring the coal from such temperature to at least the minimum temperature at which exothermic reactions are initiated in the absence of air, depositing a charge of the preheated coal in an oven, and supplying sufficient extraneous heat to the coal in the oven to coke the coal at a final temperature of at least 750° C.

4. The process of coking coal which comprises heating the coal uniformly throughout and with agitation in an air excluding container to a temperature below the minimum temperature at which exothermic reactions are initiated in the absence of air but high enough so that the exothermic heat available in the coal from exothermic reactions in the absence of air is sufficient to bring the coal from such temperature to at least the minimum temperature at which exothermic reactions are initiated in the absence of air, and coking the coal by depositing a charge of the preheated coal in an oven having its walls previously heated to a temperature between 750 and 1000° C.

5. The process of coking coal which comprises heating the coal uniformly throughout out of contact with the atmosphere and with agitation to a temperature high enough to insure the autogenous progression of exothermic reactions throughout a charge of the preheated coal when a portion thereof is heated to a temperature at which exothermic reactions are initiated, depositing a charge of the preheated coal in an oven having its walls previously heated to a temperature of at least 750° C. and supplying sufficient extraneous heat to the coal charge in the oven to bring at least a portion of said charge to a temperature at which exothermic reactions take place and to coke the coal.

6. The process of coking coal which comprises heating the coal uniformly throughout out of contact with the atmosphere and with agitation to a temperature high enough to insure the autogenous progression of exothermic reactions throughout a charge of the preheated coal when a portion thereof is heated to a temperature at which exothermic reactions are initiated, and coking the coal by depositing the coal in an oven having its walls previously heated to a temperature of approximately 950° C.

7. The process of coking coal which comprises heating the coal uniformly throughout out of contact with the atmosphere and with agitation to a temperature high enough to insure the autogenous progression of exothermic reactions throughout a charge of the preheated coal when a portion thereof is heated to a temperature at which exothermic reactions are initiated, depositing the coal in an oven having its walls previously heated to a temperature of approximately 950° C. and supplying sufficient extraneous heat to the coal in the oven to coke the coal at a final temperature above 750° C.

8. The process of coking coal which comprises heating the coal uniformly throughout out of contact with the atmosphere and with agitation to a temperature high enough to insure the autogenous progression of exothermic reactions throughout a charge of the preheated coal when a portion thereof is heated to a temperature at which exothermic reactions are initiated, depositing the coal in an oven having its walls previously heated to a temperature of approximately 950° C. and supplying sufficient extraneous heat to the coal in the oven to coke the coal at a final temperature in the neighborhood of 950° C.

9. The process of coking coal which comprises uniformly heating the coal out of contact with the atmosphere and with agitation

to a temperature between a value close to the critical temperature of the coal and a lower value high enough to insure the autogenous progression of exothermic reactions throughout a charge of the preheated coal when a portion thereof is heated to a temperature at which exothermic reactions are initiated, depositing a charge of the preheated coal in an oven and supplying sufficient extraneous heat to the coal charge in the oven to bring at least a portion of said charge to a temperature at which exothermic reactions take place and to coke the coal.

10. The process of coking coal which comprises uniformly heating the coal out of contact with the atmosphere and with agitation to a temperature between a value close to the critical temperature of the coal and a lower value high enough to insure the autogenous progression of exothermic reactions throughout a charge of the preheated coal when a portion thereof is heated to a temperature at which exothermic reactions are initiated, depositing a charge of the preheated coal in an oven, and supplying sufficient extraneous heat to the coal charge in the oven to bring at least a portion of said charge to a temperature at which exothermic reactions take place, and to coke the coal at a final temperature in the neighborhood of 950° C.

11. The process of coking coal which comprises heating the raw coal to a temperature of from 100 to 120° C. by direct contact with heating gases, indirectly heating the coal uniformly throughout and with agitation from such temperature to a temperature high enough to insure the autogenous progression of exothermic reactions throughout a charge of the preheated coal when a portion thereof is heated to a temperature at which exothermic reactions are initiated, and coking the coal by depositing a charge of the coal in an oven having its walls previously heated to a temperature above 750° C.

12. The process of coking coal which comprises heating the coal uniformly throughout in an air excluding container and with agitation to a temperature not appreciably higher than the critical temperature of the coal but high enough to insure a material reduction in the oxygen content of the coal, depositing a charge of the coal so heated in an oven, supplying sufficient heat to the coal in the oven to convert the charge into coke at a final temperature above 650° C., and maintaining the coke in the oven without substantial increase in the temperature thereof over the said final value until the volatile content of the coke has been reduced below the value of volatile content at the time that the said final temperature is first attained.

13. The process of coking coal which comprises heating the coal uniformly throughout in an air excluding container and with agitation to a temperature not appreciably higher than the critical temperature of the coal but high enough to insure a material reduction in the oxygen content of the coal, depositing a charge of the coal so heated in an oven, supplying sufficient heat to the coal in the oven to convert the charge into coke at a final temperature above 650° C. and maintaining the coke in the oven without substantial increase in the temperature thereof over the said final value until the temperature of reactivity of the coke has been increased to a value higher than the temperature of reactivity of the coke at the time that the said final temperature is first attained.

14. The process of coking coal which comprises heating the coal uniformly throughout in an air excluding container and with agitation to a temperature not appreciably higher than the critical temperature of the coal but high enough to insure a material reduction in the oxygen content of the coal, depositing a charge of the coal so heated in an oven, supplying sufficient heat to the coal in the oven to convert the charge into coke at a final temperature of above 750° C. and maintaining the coke in the oven without substantial increase in the temperature thereof over the said final value until the volatile content of the coke has been reduced below the value of volatile content existing at the time that the said final temperature is first attained.

In testimony whereof we affix our signatures.

SAMUEL W. PARR.
THOMAS E. LAYNG.