This invention relates to a new and improved process for treating hydrocarbon-containing fuels such as coal and the like in powdered form, including the step of low temperature carbonization for the recovery of coal gas and other products resulting from carbonization and a powdered coke, whereby, if desired, be fed directly to a combustion chamber without appreciable loss of heat from the carbonizing process and burned with highly satisfactory results.

The characteristic feature of this invention deals with the treatment of powdered hydrocarbon-containing fuel, such as coal, including an oxidation pre-treatment and subsequent low temperature carbonization and, in addition, special provisions in mechanically handling and controlling the movement and condition of the fuel while being subjected to the pre-oxidation and carbonization treatments resulting in the production of powdered coke and the elimination of all tendency to cake or to in any wise clog the apparatus, and, for the first time, in a successful performance of this type of treatment.

Prior to this invention, low temperature distillation was known to be desirable in many instances, and numerous attempts have been made to successfully perform low temperature carbonization with both lump and powdered fuels. With the increasing use of powdered coal, it was considered highly desirable to endeavor to perfect a process for carbonizing powdered coal for the recovery of coal gas and other products of distillation and with the aim of acquiring a powdered coke suitable for use in ordinary pulverized fuel furnaces.

The difficulty, however, which prior to the present invention, has blocked the successful development of such a process, flows from the tendency of coal to cake under the temperature and treatment necessary for a satisfactory carbonizing action which has not only destroyed the possibility of recovering a powdered coke for fuel purposes but has without exception, caked in and clogged the apparatus to an extent which rendered the undertaking entirely impractical and unsuccessful from the commercial standpoint. It is this caking quality of coal that has also prevented the development of a successful continuous treatment process of the type of this invention.

Among the methods heretofore devised in an effort to successfully carbonize powdered coal with a resulting powdered coke included a pre-heating and/or oxidizing treatment, and whereas oxidation is known to free coal of its caking properties, the utilization of this known discovery has thus far baffled those skilled in the art insofar as the development of a commercial workable process is concerned, which would not suffer the defect of ultimate caking failure.

Accordingly, it is an object of this invention to provide a new and improved process including pre-oxidation and subsequent carbonization of powdered fuel and the recovery of the products of carbonization together with the production of a powdered coke, which coke exhibits no tendency to cake either as finally recovered or at any stage of the process in treatment.

As an incident to the above stated object, it is a further object to provide a process which may be run continuously and, if desired, in connection with which the powdered coke may be fed, while still hot, from the carbonizing retort into a suitable combustion chamber such as a furnace used for any desired purpose such as for instance, in heating steam boilers of a generating plant or any other practical purpose.

It is a further object of this invention to provide a process which is highly satisfactory in performance and is well adapted to economical and successful commercial installation whereby when used in conjunction with a furnace, high efficiency is realized both in the combustion of the powdered coke and generation of heat and in the recovery of the desirable products of low temperature carbonization.

It is a further object of this invention to provide a process for accomplishing the above stated objects which will utilize for treatment, powdered fuel such as coal or the like, and produce, in addition to the by-products of the carbonizing treatment, a coke fuel in powdered form which may be cooled and stored or burned directly in its heated condition, but which in either case, may be satisfactorily handled and burned in combustion chambers now used for the combustion of powdered coal.

As an advantage of this invention, the powdered coal and the resulting powdered coke may be conveyed and transferred in enclosed pipes either by gravity or by currents or drafts of air or gases, so that the entire apparatus may comprise an enclosed system which makes for a high degree of cleanliness and increased efficiency and the avoidance of wastes and other losses incident to methods differing in this respect.

It is a further object of this invention to carbonize the pulverized oxidized fuel in a closed retort by heating with gases which are isolated
from the space of the retort whereby the gas recovered is not diluted nor rendered of inferior grade or lowered B. t. u. value, as would be occasioned when heating gases are brought into direct association with the fuel in the carbonizing retort.

It is a further object of this invention when used in combination with a combustion space of a furnace to remove the hydrogen from the fuel during the carbonizing treatment, and to thereby enhance the heat value of the resulting powdered coke by preventing the formation of water vapor during combustion and eliminating the conversion of the heat of vaporization to the stack. In the accomplishment of this object, most of the hydrogen passes off with the gas in the carbonizing retort and does not enter the furnace, and it is found in practice, that the heat saved in this way more than compensates for the radiation.

When the oxidizing and carbonizing process is conducted in combination with the combustion space of a furnace, it is a further object to utilize gaseous products of combustion taken from the combustion space as a source of heat for conducting both the oxidizing and carbonizing treatments and in the oxidizing treatment to utilize such gaseous products of combustion as a conveying gaseous medium for the powdered fuel. In this latter case the gas is ultimately returned to the combustion space for the conservation of all fine fuel particles which may remain suspended therein after the oxidized fuel has been separated therefrom. In the accomplishment of this object the gaseous products of combustion during oxidation serve as an inert atmosphere containing only the desired and regulated quantity of oxygen for proper oxidation of the entire mass with assurance against combustion during the oxidizing treatment.

One aspect of this invention is based upon the more thorough knowledge of the effect of pre-oxidation in the subsequent handling and condition of the coal in passing from the point of oxidation pretreatment to the carbonizer and through the carbonizer until the carbonizing treatment is completed.

The applicant have discovered that the results of an oxidizing treatment upon a given mass of ordinary pulverized coal, for a like period of exposure under the same conditions, differ widely insofar as the caking properties are concerned, for particles of different size, that is to say, between the particles of maximum size as compared with those of minimum size. A corresponding difference exists throughout the intermediate range of particle sizes. The period of oxidation, the temperature and other factors must be substantially the same for the entire mass as it is entirely impractical from the commercial standpoint to subdivide the mass of powdered coal into numerous batches, each of a particular size, and subject each batch to a different oxidizing treatment, each designed and selected especially for properly oxidizing the particles of the particular batch.

It is furthermore impractical from the commercial standpoint to subject the entire batch to a conveyor oxidizing treatment of length sufficient to thoroughly oxidize the largest particles, on account of the fact that such treatment will involve a temperature, quantity of oxygen, and treatment period productive of combustion of the more minute particles. Inasmuch as a pre-oxidation treatment which would cause combustion of the more minute particles cannot be employed, the outstanding difficulty of processes heretofore devised and tried, insofar as the applicant's theory determine, has been that of inadequate oxidation of the larger particles, resulting in the subsequent caking of the larger particles to an extent that the apparatus employed was clogged with coked coke and the process rendered inoperable.

Accordingly, the present invention contemplates an oxidizing treatment which is substantially the same for the entire mass so that it may be supposed, if the applicants' theory is correct, that some of the larger particles will be inadequately oxidized but with a handling of the entire mass in the oxidizer and in the carbonizer in such a manner that the smaller oxidized particles serve as a coating for the larger, less oxidized particles whereby to impart to the entire mass, the quality of a larger particle. Smaller particle sizes so that under the subsequent handling during oxidizing and carbonizing a treatment which may be referred to as an average oxidizing treatment may be practiced with the result that the entire mass behaves as a completely oxidized mass. Of course, it is understood that in no case should the oxidizing treatment be increased either by the amount of heat, quantity of oxygen or treatment period, to the point where combustion will occur in the oxidizer.

According to the present invention the oxidizing treatment may be conducted in any suitable manner such as hereinafter outlined, provided however, that after separation of the fuel particles and the gaseous medium, the fuel particles are allowed to collect or settle as a static mass whereby the particles are at rest and free from disturbing or agitating forces or movements such as would operate to disassociate and separate the fine oxidized particles from their coating association on larger particles.

Furthermore, the same conditions must prevail in the carbonizing retort and accordingly, this process involves the step of carbonizing the fuel while existing in the condition of a relatively static mass free from disturbing forces or movements which would cause exposure to each other and to inner surfaces of the carbonizer of the larger partly oxidized particles. The movement of the mass through the carbonizer, essential for a continuous operation is accomplished by permitting the mass to slowly settle under the action of gravity while the volatile material is being driven off. Such movement does not disturb the condition of the mass insofar as the fine coating on larger particles is concerned and consequently there is no tendency to cake and the mass remains entirely in powdered form whereby it is free to continue its slowly settling movement until it reaches the bottom where the fuel exists as coke dust. The coke dust can then be removed by any suitable method such as by means of a conveyor oxidizing treatment of length sufficient to thoroughly oxidize the largest particles.
ceeds, however, additional advantages may be mentioned as follows:

This process is well adapted for use in electric generating plants having steam boilers equipped for the handling and burning of pulverized fuel and in such cases the apparatus for conducting this process may be conveniently placed between the pulverized fuel bunker or similar source of supply and the inlet to the combustion space without disturbing or seriously affecting the steam boiler installation.

Accordingly, the valuable volatile constituents of the coal which would otherwise be burned in the steam boiler for their heat value, may by such an installation, be separated from the residual coke dust and recovered as coal gas, coal tar and oils. The advantage of so doing will be appreciated when it is known that the commercial value of coal gas, coal tar and the other by-products of coal distillation, is considerably in excess of their heating value. The present invention therefore is productive of the profit from the volatile products and at the same time provides an adequate and satisfactory fuel in the form of coke dust for combustion in the furnace, the result of which is an increased profit on the entire operation.

A further advantage is realized from the fact that the recovered by-products are produced by low temperature distillation treatment which is productive of a gas of great value and high in heating units. This is due to the fact that a low distillation temperature does not expose the coal gas to thermal decomposition or cracking such as might impair its heating value per unit volume. The quality of the gas is also assured by the avoidance of heating gases in direct contact with the fuel in the carbonizer whereby only undiluted and clean products of distillation are recovered.

Other details of the process such as the filtering of the gas through the pulverized coal, the maintenance of the carbonizing temperature, and so forth, assist in the production of clean gas and tar products without danger of re-condensation in the carbonizing retort.

Likewise, tar of high value is produced by the low distillation temperature because high destructive temperatures in the carbonizing retort are thus avoided. The products of distillation when removed from the retort, may be recovered by condensation of the tars and oils and the collection of the gas in suitable containers, all in accordance with known and satisfactory practice.

In the drawings, two sets of apparatus are shown both of which have proven to be highly successful in practice and well adapted for large scale commercial installation.

In order that the process may be more readily understood, it will be described in connection with the disclosed apparatus but it should be understood that the invention is not to be limited by this illustrative description as the scope thereof will be pointed out in the appended claims.

This invention is a continuation in part, of applicants' co-pending application, Serial Number 556,546, filed March 28th, 1931.

In the drawings—

Figure 1 is a vertical sectional view of one form of apparatus by which the present invention may be practiced and as installed in connection with a boiler furnace;

Figure 2 is a vertical sectional view, on a larger scale, of the carbonizer disclosed in Figure 1;

Figure 3 is a cross-sectional view taken on line 2—3 of Figure 2, and on a larger scale;

Figure 4 is an enlarged longitudinal, vertical, sectional view of the oxidizer disclosed in Figure 1;

Figure 5 is a sectional view taken on the line 5—5 of Figure 4;

Figure 6 is a vertical sectional view of a modified form of apparatus by which the present invention may be practiced and as installed in connection with a boiler furnace; and

Figure 7 is an enlarged elevational view in cross-section of the oxidizer and separator shown in Figure 6.

Construction of oxidizer and separator as shown in Figures 1, 4 and 5.

By referring to Figures 1, 4 and 5 of the drawings, it will be noted that the apparatus here shown comprises an oxidizer 8 in the form of an enclosed tank or container, of substantial size. The oxidizer is provided on one side at an intermediate point in its height, with an inlet pipe 20 through which is introduced the pulverized fuel or coal to be oxidized. Pipe 20 communicates with pipe 45 which leads to a hopper, bunker, or the like for supplying pulverized coal. If desired, pipe 20 may connect directly with the fuel pulverizer.

The oxidizer is also provided with an inlet pipe 10 here shown as entering the oxidizer at the opposite side of the coal inlet pipe with its other end extending to and connected with the header 12 which is in communication with the interior of the combustion space of the furnace. From this it will be obvious that a portion of the gaseous products of combustion will be fed to the header 12, and then through pipe 10 into oxidizer 8.

Within the lower portion of the oxidizer 8 extending lengthwise thereof, is a revolving paddle wheel 13, having the central shaft 14 with suitable journal bearings in opposite sides of the container, one end of the shaft is projected through the container and carries a pulley wheel 15, for imparting a rotary motion to the paddle wheel by means of a belt 16, from a suitable source of power (not shown).

In the proper functioning of the oxidizer, pulverized coal enters at a relatively uniform rate through the inlet pipe 20 and the heating and oxidizing flue gas enters through the pipe 10. The revolving paddle wheel 13 is rotated at the desired rate of speed and thereby functions to keep the pulverized coal and the introduced heating and oxidizing gas in constant agitation.

It is to be understood that the temperature of the gas introduced into the oxidizer is to be adjusted so as to maintain an average temperature of coal and gas therein at approximately 600 degrees F. and accordingly, suitable means may be utilized in connection with gas pipe 10 for cooling down the flue gas if it should be too hot. It is desirable, however, to withdraw the gas from the combustion space at substantially the desired temperature without the necessity for cooling under ordinary operating conditions. The proper oxidation as herein above outlined is accomplished when approximately ten per cent of oxygen is contained in the gas. This is the approximate percentage found to exist in the flue gas as withdrawn from the combustion space under ordinary operating conditions but obviously it is within the scope of this invention to either further dilute the gas with an inert gas or to en-
rich it with additional oxygen, as circumstances demand.

Extending into the upper portion of the container 8 is the outlet pipe 17, having its lower end extending downwardly into the oxidizer. A vertically adjustable pipe section 18 is preferably provided, surrounding the lower end of the pipe 17 having a suitable handle member 19 by which the sleeve may be adjusted upwardly and downwardly with respect to the lower end of the outlet pipe. In this manner the entrance end of the outlet pipe may be varied at will.

Outlet pipe 17 extends to and connects with a separator 23 as shown in Figure 1. The separator is preferably of the cyclone type now supplied on the market. Pipe 17 which conveys the oxidized coal and gas from the oxidizer extends into the cyclone separator tangentially of its interior circumference. This separator serves to effect a separation of the oxidized coal from the flue gas but also functions as a collector for collecting the mass of oxidized coal in the lower portion thereof. The separated gases are caused to pass upwardly in the region of the center of the separator and to be withdrawn through the outlet pipe 24 which extends downwardly as shown in Figure 1 and if desired, may ultimately lead to the combustion space of the furnace as herein described. The removal of the gases through pipe 24 is effected by the pull of a fan 50.

The separator is provided with tapered walls at its lower portion and terminates in an outlet connection which leads directly to the carbonizer. The outlet is provided with a rotary feeder 28 which serves to discharge the coal from the separator at the desired rate while maintaining a positive seal between the separator and the carbonizer. This seal is important in maintaining a sealed atmosphere in the carbonizer and to prevent the entrance of oxygen which would cause spontaneous combustion of the highly heated coal.

The rotary feeder 28 is in the nature of a star wheel which occupies substantially the entire diameter of the outlet pipe whereby the coal in the separator is caused to accumulate above the seal to form a static mass or a mass at approximate rest but which is caused to move bodily slowly downwardly by the controlled action of the star wheel and to be deposited in the carbonizer to form a similar mass without subjecting the oxidized fuel to agitation or motion such as would destroy the coatings of the fine coal particles on the larger particles.

Operation and function of oxidizer and separator as shown in Figures 1, 4, and 5

Upon starting the apparatus, the pulverized coal collects in the oxidizing container 8, until the rate of removal equals the rate of supply. The accumulation of coal therein increases the treatment period to some extent, which, with the temperature and intimate commingling of the coal and gas, effects the desired oxidation of the coal. In this form of the invention the treatment period may be varied within limits by adjusting the vertical position of sleeve 18 surrounding the inlet end of pipe 17 so that the preferred treatment period for a particular coal may be selected.

A certain additional variation in the oxidizing treatment may be realized by varying the speed of the paddle wheel 15.

In view of the widely different results which are obtained in oxidizing various types of coal, particularly with respect to the destruction of the caking properties, it is difficult to prescribe by exact figures or tables, the degree of oxidation necessary for the best results. Although it is known that under the oxidation treatment, coal will take up oxygen, the presence of which may be accounted for by noting an increase in the weight of the oxidized coal, this characteristic is of little assistance because many commercial factors enter into the reaction, particularly with different coals and with slightly varying treatments. It is found that the increase in weight is not reliably indicative of the degree of destruction of the caking properties.

Accordingly, the most satisfactory method known to the applicants, is to conduct the oxidizing treatment substantially in the manner herein set forth and by slight variations of the controlling factors influencing the oxidizing treatment to adjust the apparatus at that point where the caking property of the mass is found by actual test, to be destroyed.

Satisfactory tests may be conducted by taking small samples from the oxidizer and after carbonizing the samples in a crucible, noting the caking properties of the mass removed from the crucible. As above pointed out, the maintenance of the coated condition (which will naturally occur) of the larger particles by the finer particles is an important factor in the success of this process. This will be appreciated when a sample of oxidized coal was taken by way of experimental test and was screened to collect those particles which would not pass through a 100 mesh sieve, and to collect those particles which would pass through a 325 mesh sieve. Upon oxidizing the larger particles alone, a hard cake of coke was formed, and yet, a carbonized sample composed of a mixture of fifty percent of the coarse particles and fifty percent of the fines, produced a coke dust which exhibited no caking properties whatsoever.

In the oxidizer here described, the passage of the particles is upwardly and as a natural result, the finer particles will pass out to the separator more rapidly than the coarser particles and whereas this tends to increase to some extent, the oxidation period for the larger particles it is nevertheless necessary for a successful operation to maintain a coating of fine particles on the larger particles as above pointed out.

Merely as a guide and without unduly limiting this invention, it may be stated that the oxidizing temperature in most cases will be substantially 600 to 650 degrees F. and the average treatment period will be approximately thirty seconds. In this form of the invention, the necessary variations in the oxidizing treatment may be effected by altering the temperature, adjusting the outlet sleeve 18 or modifying the turbulence produced by the paddle wheel.

Precaution and care should be exercised in performing the oxidizing operation to avoid the existence of conditions in the oxidizing retort productive of combustion. Combustion is, of course, undesirable from the standpoint of dissipation of the gaseous and coke products but in addition it is productive of a high degree of heat which would cause further combustion and thus destroy the entire object of the process.

It is therefore necessary to provide only a limited amount of oxygen in the oxidizing gas which is determined on the basis of the amount of coal treated and the oxidizing temperature. If difficulty is encountered in the securing of non-caking properties for the mass as a whole when
oxidized and carbonized in accordance with the teachings of this invention, this invention further contemplates increasing the percentage of finer particles which will be found to solve the problem.

With this apparatus, the coated condition of the larger particles with the fines is preserved by the action of the oxidized mass in the base of the separator, and the success of the process involves the continuous handling of the fuel mass from this point to the completion of the carbonizing operation without agitation or subjection to disturbing forces or movements such as would cause a separation of the fine and large particles. The relatively slow downward movement of the mass through the base of the separator by means of the star wheel seal and the subsequent deposition of the coal into the carbonizer at a rate sufficient to maintain a large mass therein, serves to produce a non-caking carbonizing action resulting in a coke dust which may be continuously extracted from the base of the carbonizer and an entirely continuous carbonizing action.

An important and characterizing difference between the process of this invention and those of the prior art is that of providing an oxidizing treatment which is productive of non-caking properties in a mass of pulverized coal, when subjected to a carbonizing treatment under such conditions that the larger particles are coated with the fines, together with the use of a pulverized coal composed of a sufficient percentage of fines to produce non-caking properties in the mass under oxidizing conditions which are free from liability of causing combustion in the oxidizer.

The above described oxidizing and separating apparatus has been found to give good results in practice but obviously other types may be employed.

By way of illustration, the modified form of oxidizer and separator will now be described.

Construction of oxidizer and separator shown in Figures 6 and 7

By referring to Figures 6 and 7, it will be noted that the pulverized coal is oxidized, and separated and collected in the same container which is constructed in the general form of the usual cyclone separator. Centrally of the top is a smaller cylindrical chamber 67 which serves as a vestibule space for the tangential introduction of pulverized coal to be treated. In this form, the coal is fed into the oxidizer through pipe 62 which is connected with any suitable source of coal, such as an overhead bunker, hopper or if desired, directly with the pulverizing mill. The container is preferably cylindrical in shape at its top portion and is provided with inclined conical walls 63 at the bottom portion terminating in an outlet pipe 64. The outlet pipe leads directly to the carbonizer 65 as shown in the drawings.

When this apparatus is used in connection with a furnace it is preferable to use flue gases for the oxygen and heat carrying medium which is fed into the oxidizer tangentially as at 66 through a pipe 67. By virtue of the tangential inlet, the gases are given a whirling motion into which the coal falls from the vestibule chamber 61. Due to the action of the centrifugal force the coal is thrown outwardly against the walls of the oxidizer but only after the particles thereof have been exposed to the heating and oxidizing effect of the flue gas. By virtue of this action, a separation also occurs as the gases free from coal particles are caused to occupy the central portion of the container where they are withdrawn through an outlet pipe 68 which extends upwardly and thence downwardly and connects with a suction fan 69.

In order that more accurate control over the oxidizing action may be realized, provision is made for re-circulating a desired amount of the treated coal after it has fallen and collected at the bottom of the container as shown at 70. This means comprises an outlet pipe 71 which connects with an intake of a fan 72 which fan discharges upwardly through pipe 73 tangentially back to the vestibule chamber 61. The inlet here shown is on the opposite side from the inlet of the coal feeding pipe 62.

It should be noted that the re-circulated coal will be likewise discharged into the central portion of the oxidizer whereby it will again be exposed to the heating and oxidizing effect of the flue gas.

In the outlet pipe 64 which leads to the carbonizer, a modified form of sealing device is shown which comprises two star wheels 74 and 75. Each wheel is designed to occupy substantially the entire interior space of the outlet pipe whereby coal is fed to the carbonizing reaction 61 along the convex surface and thereby by rotation of the star wheels. To avoid leakage of coal gas past the seal a flue gas pressure equal to or slightly above the pressure in the carbonizer is maintained between the star wheels. This is accomplished by connecting a pipe between the discharge of fan 69 and the space between the star wheels. Other means are possible for providing a gas-tight seal and for con-veying coal from the oxidizer to the carbonizer.

As shown in Figure 6, flue gas pipe 67 is in communication with flue gas pipes 76 and 77 respectively, both of which communicate with the flue gas passages from the furnace for withdrawing 115 flue gases therefrom.

It will be noted, however, that these pipes take gases from different portions of the flue gas passages and consequently at different temperatures whereby a mixture of gas may be fed to the oxidizer by adjustment of valves 78 and 79 respectively, to supply any desired temperature. Valve 78 is located in the pipe 80, which extends from the pipe 77 to pipe 67 at a point above valve 79. Pipe 77 also conveys flue gas to pipe 82 which is 125 here shown as an extension of pipe 67 and which ultimately leads to the heating elements in the oxidizer. Valve 81 serves to separate the upwardly flowing gas from the downwardly flowing gas but by means of these valves and valve 82 located in pipe 77, any desired temperature may be provided either in the oxidizer or the carbonizer. In addition, the pipe 67 is provided with an air bleed pipe 84 provided with a valve 85 by which additional air may be introduced into the flue gas.

Operation of oxidizers and separators shown in Figures 6 and 7

In operating this form of apparatus, the coal is introduced centrally of the container as above described and the flue gas enters tangentially to establish a whirling motion. The coal falls downwardly from the vestibule space 61 and upon entering the oxidizer, the coal and flue gas is set in rotary motion which thoroughly exposes the coal to the oxygen and the flue gas and causes oxidation to that degree which effectively destroys the caking property of the mass of coal.

During the oxidizing treatment, the coal is con-
tinuously separated from the gas by centrifugal force as it is thrown outwardly toward the walls of the oxidizer and the gas travels inwardly and is discharged through the outlet pipe 66. The 5 coal then moves by the action of gravity down the inclined walls at the lower portion of the container and collects at the bottom thereof for subsequent discharge into the retort. If greater oxidation is necessary, the re-circulating fan 10 is put in operation whereupon any desired portion of the coal may be again introduced at the top, and exposed a second time to the oxidizing treatment. This re-circulation enables a wide variance in the degree of oxidation as it is possible, if found necessary, to adjust the capacity of the re-circulating fan relative to the flow of coal through the oxidizer in a manner to assure re-circulation two, three or more times.

The re-circulation means another important function which is that of withdrawing gas from the bottom of the separator which has been found to improve the efficiency of the separator. Furthermore, re-circulation maintains more coal in the oxidizer and thus provides an increased mass of coal furnishing heat which enables the reduction in the amount of heating flue gas required for thorough oxidation. Reduction in the flue gas flow increases the time that coal is in the oxidizer and further improves the oxidizing action. This principle of separating the coal from the flue gas and re-circulating it is invaluable in reducing the size of the oxidizer and incidentally minimizing surface heat losses. To increase the time element by increasing the size of the oxidizer only works a hardship if re-circulation is not practiced.

The time that the coal is in the oxidizer is proportional to the time that gas is also present, other conditions being equal. Therefore, re-circulating all the coal once, is equivalent to doubling the oxidizer size.

Published tests show that the rate of oxidation does not slacken until after the caking properties are destroyed. Therefore, having some coal particles pass to the carbonizer with only one passage through the oxidizer, is not undesirable since other particles may re-circulate more times than the average and are oxidized proportionally.

This form of apparatus likewise provides a collected mass similar to the mass collected in the separator in the form previously described. At the end of the oxidizing action the minute particles will adhere themselves with or affix themselves to the larger particles and form a coating thereon when collected as a mass at substantial rest in the base of the oxidizer and subsequently fed to the carbonizer, the desired conditions are maintained for assuring non-caking properties in the mass as a whole.

**Oxidizing treatment**

For successful destruction of the caking properties of coal, the following conditions must be satisfied:

1. Temperature must be adequate.
2. Time of treatment must be sufficient.
3. Enough oxygen must be present.
4. Oxygen must be brought into thorough contact with coal.

Temperature accelerates the process markedly. It is common knowledge that weathering of coal reduces its caking properties. Yet years of exposure are necessary to totally destroy caking of most coking coals. Most chemical reactions are doubled with each 10° C. increase of temperature, which explains why the oxidizer described herein can be effective.

Temperature of the coal and flue gas mixture is normally regulated slightly under the initial distillation temperature of the coal being processed. For most coals, this temperature ranges between 500 and 700° F. The oxidation temperature employed may slightly exceed the initial distillation temperature to deliberately sacrifice by-product yield in favor of more thorough oxidation. Since tests have shown that oxidation decreases tar yield and increases gas yield, thorough oxidation at high temperatures may be desirable in some cases.

With this invention the oxidizer serves as a preheater for the carbonizer, efficiently heating the coal nearly to its distillation temperature and thus greatly reducing the size of the heating plates and the consumption of heat in the carbonizer. In the last described form, any desirable temperature can be obtained in the oxidizer by proper proportioning of the hot and cooler flue gases. Some heating occurs due to the oxidizing in the oxidizer which serves to reduce the amount of hot gases utilized. The active swirling of coal and gases serves to maintain uniform temperatures in the oxidizer.

Time of contact between coal and oxygen as obtained in the cyclone type of oxidizer is sufficient for good results because the coal particles move relatively slowly to the walls and downwardly to the feeder. The coal is thus concentrated, and the weight of coal in the oxidizer at any one time will be considerably in excess of the weight of flue gas and coal without such concentration. This principle of concentration greatly reduces the requisite size of the oxidizer. This concentration of coal in the oxidizer is especially true of the finer particles, for they travel most slowly to the walls. As above pointed out, experience has been shown that the coarser particles of pulverized fuels cannot be oxidized with practical success, and that only the fines need be oxidized to prevent caking of the mixture. A type of oxidizer that would retain the coarse particles at the expense of hurrying the fines would thus be less effective. Non-caking fine particles surrounding or coating caking coarse particles prevent caking of the whole and allow maintenance of the mass in pulverized form throughout the carbonization process.

Preferential oxidation of small fines affords attainment of relatively high tar yields if desired. It is known that oxidation of coal decreases tar yield, though with an increase of gas yield. In situations where tar is more valuable than gas, this special feature of obtaining non-caking properties by oxidizing only a fraction of the total coal, is valuable.

In some coal experiments show that, though oxidation increases gas yield at the expense of tar yield, the sum of heat units in the two products is reduced. When tar and gas are equally valuable, it is thus desirable to effect destruction of caking properties with minimum oxidation. Such is possible by the process of this invention.

By selecting larger oxidizers of the cyclone type or by increasing the recirculation of the coal, the time which coarse and fine particles remain in the oxidizing atmosphere can be increased to obtain higher gas yield from carbonization. Increase of the flue gas inlet pipe size reduces the whirling velocity of the gas in the oxidizer and decreases the centrifugal force causing slower coal movement to the walls and thus increases the time of oxidation.
This invention contemplates the use of all types of oxidizers and separators so long as they satisfy the above-mentioned requirements. It is important that no flat surfaces on which coal may collect be present and that the separators have reasonably high efficiency so that too large a percentage of coal will not by-pass the carbonizer. Though the heat value of coal by-passing the carbonizer may be conserved in the furnace, high separation efficiency is highly desirable because the most thoroughly oxidized and most non-caking particles, the fines, are otherwise lost to the furnace.

Proper oxidation temperatures will depend upon the caking properties of the coal employed, the degree of oxidation desired to increase gas yield, and the amount of preheating wanted. The usual range is between 500 deg. Fahr. and 700 deg. Fahr., though unusual conditions may dictate more or less. To reduce the oxidizer and carbonizer investment cost, the use of temperatures above which a small amount of volatile matter is lost, may be found desirable. The oxidizer is a much more efficient heater than the carbonizer, and the volatile lost is generally large.

No heat units are lost since the discharge is burned in the furnace.

Oxidation with flue gas, as shown in this particular disclosure, is desirable because its high efficiency of oxidation permits completion of the reactions with a less percentage of necessary oxygen than in carbonizing. Flue gases prevent the possibility of explosion, since the rate of spontaneous heating in low oxygen mixtures is too slow to cause sudden increase of pressure. Hot flue gases are most readily obtained in a power plant, and in fact if their heat can be absorbed in other equipment than existing boilers, economizers, or air heaters, overall plant efficiency is increased. This invention contemplates recirculation of flue gases which in itself is not ordinarily more efficient, but since it reduces boiler duty, it does improve heat absorption efficiency.

In cases where flue gases and transport air do not contain sufficient oxygen, room air or preheated air can be added as described above. If only heated air or other gases are needed, the plan does not preclude the use of this type of oxidizer may be used with various types of carbonizers one or more oxidizers may be used for each carbonizer, depending upon length of the carbonizer bin and resulting levelling of coal above the carbonizer plates. Small separators are more efficient mechanically than large ones, though the latter cost less, occupy less space and suffer smaller heat losses.

**Construction of carbonizer as shown in Figures 1, 2 and 3**

The carbonizer 21 is in the form of a large container of rectangular form having a lower tapered portion 21'. Within the lower portion of the main body portion of the enclosure the carbonizing apparatus is disposed. Said carbonizing apparatus comprises a plurality of sheet metal heating elements 29 of envelope-like form, as shown most clearly in Figs. 2 and 3. Depending into the container 21 from the flue gas header 12 are a plurality of flue gas inlet pipes 30. An end portion of a heating element 29 opens into each of the pipes 30 so that no flue gas will be introduced into the envelope-like heating elements 29. The opposite ends of the heating elements open into flue gas outlet pipes 31 disposed within the opposite side of the container 21 and said pipes 31 extend upwardly outwardly of the container and discharge into the header 25 from which the pipe 26 extends, which conducts the gases back to the boiler furnace. Baffles 32 and 33 are positioned within the envelope-like heating elements to cause a flow of gases therethrough in the manner indicated by arrows in Fig. 2.

There are also within the container 21 forming part of the carbonizing apparatus, vertical coal gas off-take pipes 34, which pipes are perforated and covered with fine screen throughout their length. The lower end portions of said pipes 34 connect with horizontal coal gas manifolds 35, which manifolds discharge into a coal gas off-take header 36 extended externally of the container 21.

With reference to Fig. 1, it will appear that pulverized coal branch pipe 20 lead off from the furnace 48, the upper branch pipe 20 extending to the oxidizer and the lower pipe 20 extending to the bin portion of the carbonizer 21. Normally the lowermost valve 22 is closed and therefore all the pulverized coal is directed into the oxidizer and is treated therein before reaching the bin 21. This is the case during usual distillation operations. However, if for any reasons the distillation apparatus is not functioning, then the upper valve 22 is closed and the lower valve 23 is opened, whereby untreated pulverized coal is routed directly to said bin or container 21. In this event no heat is applied to the carbonizer plates and the operation of the apparatus is the same as that practiced in similar apparatuses having no distillation apparatus incorporated therewith.

Coal gas is evolved from the coal between the heating elements 29 and said coal gas travels horizontally to the screened gas off-take pipes 34. Pulverized coal permits passage of a considerable gas flow, especially upwardly, and a head of coal above the screened open ends of the gas off-take pipes 34, the pipe 26 effectively seals the same from the steam space thereabove. Suction of an exhaustor positioned as at 37 in Fig. 2, which acts on the gas off-take pipes, or slight steam pressure above the coal within the container 21, introduced thereinto through a steam connection 46, maintains the gas flow downwardly, but little flow occurs in this direction due to the packing tendency of the coal. The coal gas taken off through the header 36 is cooled and collected in any standard 125 apparatus for that purpose (not shown) and tar is condensed.

After carbonization in the member 21, the resulting semi-coke, still in pulverized form, gravitates through the lower tapered portion 21' of the container to a suitable coal feeder 38, which coal feeder is driven from a suitable source of power (not shown) by a belt 39. The coal feeder passes the semi-coke into the lower vertical tubular connection 27 from where it is introduced directly into the boiler furnace, and with the introduced coke, gas, passing through the pipe 36, is also introduced into the boiler furnace. The introduced coke has a temperature of about 1000 degrees Fahrenheit, which compensates for its reduced volatile content in facilitating combustion and it is burned like untreated coal. The heat generated from said burning fuel boils water within a boiler member 40 above the furnace and steam is taken off through a pipe 41 for operating any desired equipment.

**Construction of carbonizer as shown in Figures 6 and 7**

This form of carbonizer comprises a container 100
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65 which is of substantially the same shape as that of the apparatus previously described, including heating elements of substantially the same character but differing in the means and mechanism for withdrawing the volatile gases distilled from the coal. The upper portion of the container is provided with vertical walls whereas the base thereof, has tapering walls 101 as shown in Figure 6. At a point intermediate the height of the container are a plurality of heating elements 102, spaced apart to provide slot-like spaces therebetween, which heating elements are hollow and in general constructed as those previously described. They are preferably provided with internal partitions 103, providing a circuitous path for the heating gases passing therethrough. The heating element through an inlet pipe 104 which pipes are supplied with hot flue gas from header 105 received from pipe 82, taken from the combustion space of the furnace as previously described.

At the opposite side of the elements at the top, the gases are withdrawn through pipes 106 which lead to header 107 which is in communication with pipe 68, leading to the suction fan 69.

In addition, the heating elements may be provided with fins 120 which project laterally from the flat plate surfaces thereof and which are preferably formed of thin strips of steel extending vertically and at right angles to the faces of the heating plates.

These plates may be placed at frequent intervals in order to assist the heat transfer efficiency. In practice it is found that the heat transfer on the flue gas side of the plates is considerably more favorable than that on the coal side and thus extension of the surface on the coal side is desirable.

The fins constitute a means of reducing the distance through which heat must be conveyed through the coal. When constructed in the manner described, they project into the coal and contact coal on both sides and by being made thin, they serve as little or no obstacle to the downward passage of the coal. The use of such fins improves the efficiency of the heater as it is found that the heat conduction through the fins is approximately 250 times greater than heat conduction through pulverized coal.

It will be noted that the suction fan 69 also withdraws gases from the oxidizer and carbonizer through pipe 68 and that thereafter all of the gas is discharged through pipe 108 to a header 109, and thence through pipe 110 into the coke dust feed pipe 111. Coke dust feed pipe 111 discharges directly into the combustion space of the furnace whereby the coke dust is burned as the heating fuel. The coke dust is extracted from the bottom of the carbonizing container by any suitable means such as a screw conveyor 112, actuated by a pulley 113 rotated from any suitable source of power (not shown). In this form of the invention, a super-heater may be provided comprising one or more hot gas pipes 114, extending through the upper portion of the space in the carbonizer and connecting with the flue gas pipe 82 at their inlet ends and flue gas pipe 68 at their discharge ends, whereby hot flue gases may be circulated therethrough at a temperature substantially equal to that of gas entering the heating elements of the carbonizer. This may or may not be employed as described, but its function is that of preventing the condensation of tar and oil on the carbonizer walls above the coal space and incidentally of exerting a cracking action, if desired, on the volatile gases of distillation for purposes hereinafter described.

In this form of the invention the gases of distillation are taken off the top through an outlet pipe 115 leading to a header 116 which conveys the gases to suitable cleaning and condensing apparatus after which the separated constituents may be recovered and stored in the usual way.

Insofar as the structure goes, it is important to observe that the carbonizing container is adapted to be kept constantly filled with oxidized, pulverized coal up to a point substantially as represented by the line 117 in Figure 6. As previously mentioned in connection with the collecting operation, the pulverized coal is thus allowed to accumulate as a mass which is free from disturbing forces or movements, such as would tend to separate the fine and large particles. To characterize this condition of the coal it is here referred to as a "static mass" although it is to be understood that the mass is free to settle downwardly by the action of gravity as it undergoes carbonization.

The plate-like heating elements are disposed vertically so as to permit the free passage of the coal downwardly at a rate determined by the rate of extraction from the bottom by the screw conveyor 112. An important aspect of the process with regard to carbonization is that of providing the oxidized pulverized coal in the form of a mass when exposed to a carbonizing treatment whereby all tendency to cake is eliminated.

By virtue of this treatment, the coal, after oxidation in the above described manner, behaves as a completely oxidized mass and thereby continues to exist in pulverized form and passes downwardly through the carbonizer without caking and is finally extracted in the form of a coke dust.

Under the influence of the screw conveyor, the coke dust is readily fed through the fuel inlet 111, into the combustion space of the furnace. It is not essential to this invention to introduce the returned flue gases into the fuel inlet pipe 111, as is here shown, but this is found to assist in the conveying action and to cause the fuel to be supplied in the combustion space in a desirable manner.

By returning the flue gases all of the fuel particles which may have remained suspended in the gases withdrawn from the oxidizer, are returned to the furnace with the consequent saving of their heat value.

Operation of carbonizer

In operation, when the coal treating apparatus of this invention is used in connection with a furnace, the carbonizing container may be an existing structure or it may be built especially for the process. It is possible to use containers interchangeably for untreated and oxidized coal because by proper manipulation the change from one kind of coal to the other may be made without interfering with the boiler operation.

If the carbonizer is operating and coke is being fed to the furnace the change to the feeding of untreated coal may be made by gradually cooling the carbonizer plates, and then shutting off the supply of oxidized coal to the container and turning on the supply of untreated coal. If the carbonizer is not operating and untreated coal is being fed to the furnace the change to feeding coke dust may be made by turning on the supply of oxidized coal and when the untreated coal in the container has reached a level below the car-
bonizer heating elements, the hot flue gases may be turned on and the carbonizer heated to operating temperature. Slow variation of coal temperature leaving the oxidizer and elimination of heat from the carbonizer plates can afford any degree of coal temperature to facilitate the changing of operations. The sole requirements of the container consist of sufficient size for installation of adequate heating surfaces and of its proper design to allow fairly uniform flow past these heating surfaces. Need of insulation is obvious.

The heating surfaces in the carbonizer may take any form commensurate with their efficient performance, reasonable cost, and proper maintenance. As shown in Figure 6, plates of envelope shape through which the heating gases may pass are preferable, but tubes or other types of heating surfaces may be employed. Carbon steel, stainless steel, carbonized steel, or other materials resistant to deterioration by high temperatures may be employed. Carbon steel allows heating of the coke dust to a temperature of 1000 degrees F., and other metals, if utilized, may extend the limit to 1500 degrees F.

Efficient heat transfer is the most important requirement of these heating surfaces. Short distance of heat transfer from the heating surfaces to the center of coal strata heated is of major importance, since pulverized coal is a very poor conductor of heat. Approximate countercflow of flue gas and coal is likewise important for maximum efficiency. The heating surfaces should not cause undue restriction to the downward flow of coal, and preferably should displace a minimum volume of coal in the container so that a maximum time of contact for heating may occur. In present average power plant practice, coal falls in pulverized fuel containers 6 plates of about one foot per hour. Making the heating surfaces high and of small displacement of volume affords long time of contact.

Since the sustained strength of steels at high temperature is very low, it is important that the heating surfaces be of efficient design from the strength standpoint. Each element of the surfaces should have a high section modulus when considered as a horizontal beam so that maximum stresses causing sagging may be below the ratio creep limit of the material employed.

Oxidation of the steel is low because of low oxygen content in the flue gas and coal gas. Applying fins on the plate-type surfaces as above described, is more efficient than applying them to tubes because in the former case all fins are parallel and the distance of heat transfer through the layers of coal is uniform. When used on tubes radially this same distance varies widely and causes inefficient transfer. Since strength of these fins is not important they may be made of less expensive material than the heating plates.

Slow heating of coal in the carbonizer is a special feature reducing possibility of caking. It is generally known that rapidity of heating increases the degree of caking. In the usual case where plates four feet high are employed approximately four hours continual, uniform heating is required to carbonize coal.

Continual motion throughout the carbonizing process further reduces tendency of caking.

Upward passage of coal gas through the coal being carbonized is a further means of insuring non-caking and uniform coal flow between the heating plates. This upward gas flow prevents mechanical packing of the coal and causes a continual maintenance of a very fluid, low-density mixture of coal gas and coal. Thoroughly aerated pulverized coal weighs approximately 35 pounds per cubic foot, yet lamping of the container holding this coal allows reduction of the specific volume to the point that fifty-five pounds per cubic foot density occurs. When packed to this density, the coal is almost self-supporting in a vertical pipe and its downward flow is not dependable. However, an aerated coal weighing 35 pounds per cubic foot resembles water in its fluidity. This feature of maintaining the pulverized coal in an aerated state throughout its flow between the heating plates is very important towards success of the process.

In addition to the above results obtained by reason of the upward passage of coal gas through the coal being carbonized, it has been found that this action is important in attainment of effective heating of the coal mass. The coal gas passing upwardly through the coal mass carries with it considerable heat and the heat so carried serves to heat the coal so that the coal is heated more effectively than it would be if heated merely by conduction alone from the envelope-like heating elements.

Coal dust separation from the coal gas occurs by subsidence, for the upward velocity of the coal gas is extremely low. If the oxidized coal is introduced in the carbonizer without undue dust disturbance experience shows that coal gas drawn from the top of the coal container is exceedingly clean.

If tar of maximum quantity and value is desired it will be obtained from this design, since immediately upon distillation of the coal it enters regions of no higher temperature. There is no cracking of the tar to inferior products. Though it is retained in the coal gas space above the coal for some appreciable period of time, cracking at this point is minimum because of the temperature existing there, unless the superheater is used for cracking purposes as described later.

High B. t. u. gas is obtained from the process because there is little or no dilution by the heating flue gas and because there is no cracking to deteriorate the heating value.

If it is desired to obtain a high gas yield at the expense of the tar yield, super-heating surfaces can be installed in the coal gas space at the top of the container for the purpose of cracking part of the tar vapors to gas. Tests have shown that exposure of these tar vapors to a temperature of 1300 degrees F. for an appreciable period of time may halve tar yield and double gas yield. The time element is important for this tar cracking and utilization of the large space in the top of the carbonizing container is desirable from this standpoint. These super-heating surfaces will also have the merit of preventing condensation of the tar on walls or the top of the container especially when starting and shutting down.

If the carbonizer discharges coke dust too hot to feed in existing apparatus, similar surfaces through which cold air is passed may be used below the carbonizer to cool the hot coke. Heat in the cooling air can be conserved by using it for combustion of coke dust in the water-gas apparatus.

It should be understood that it is not intended to limit the present invention to the exact steps of the method specifically described herein and as carried out in the several apparatuses shown and described by way of illustration, for various modifications within the scope of the appended
claims may occur to persons skilled in the art. What is claimed is:

1. The process of producing coke in a powdered state which consists in subjecting pulverized caking coal made up of fine particles and coarser particles, with a sufficient proportion of fine particles to ultimately insulate the coarser particles from caking together, to an oxidizing treatment non-productive of appreciable combustion and in the presence of an oxygen-containing gas, collecting the oxidized coal as a substantially static mass and in substantially the original proportion of fine and coarse particles, and subsequently subjecting said collected substantially static mass to a carbonizing heat while maintaining said mass free from disturbing movement or forces which would tend to dissociate the fine and coarser particles, whereby the carbonization is carried on without mass caking to produce a residue of coke dust.

2. The process of producing powdered coke from caking coal which has been pulverized to provide particles of graduated size ranging from fine to relatively coarse particles, which consists in subjecting said pulverized coal to an oxidation treatment wherein the coal particles are exposed to an oxygen-containing heated gas for a period sufficient to substantially completely oxidize only that portion of the smaller particles requisite, in a collected mixture, to separate and isolate the remaining larger particles therein and to thereby render the entire mass non-caking in character, collecting the oxidized coal as a substantially static mass and in substantially the original proportion of fine and coarse particles, and finally carbonizing said mass by subjecting it to a carbonizing heat while avoiding disturbing movement or forces which would tend to dissociate the fine and coarser particles, whereby carbonization is carried on without caking of the mass for the production of a residue of coke dust.

3. The process of oxidizing pulverized coal and caking it which comprises, establishing a whirling current of hot oxygen-bearing gas traveling in a path from the outside inwardly toward the axis of an enclosed chamber, introducing centrally of said chamber and adjacent the top thereof said pulverized coal, causing said coal to pass outwardly under the action of centrifugal force in opposition to the travel of said gas and downwardly under the action of gravity, accumulating said coal adjacent the bottom of said chamber while withdrawing said gas from the region of the axis of said chamber, and subsequently subjecting said coal to a carbonizing heat to produce a residue of coke dust.

4. A process of producing coke in a powdered state which consists in subjecting pulverized caking coal made up of fine particles and coarser particles, with a sufficient proportion of fine particles to ultimately insulate the coarser particles from caking together, to an oxidizing treatment non-productive of appreciable combustion and in the presence of an oxygen-containing gas, collecting the oxidized coal as a substantially static mass and in substantially the original proportion of fine and coarse particles, and subsequently causing said mass to slowly move downwardly while subjecting it to a uniform carbonizing heat free from disturbing movement or forces which would tend to dissociate the fine and coarser particles whereby the carbonization is carried on without mass caking to produce a residue of coke dust.

5. A process of producing coke in a powdered state which consists in subjecting pulverized caking coal made up of fine particles and coarser particles, with a sufficient proportion of fine particles to ultimately insulate the coarser particles from caking together, to an oxidizing treatment non-productive of appreciable combustion and in the presence of an oxygen-containing gas, collecting the oxidized coal as a substantially static mass and in substantially the original proportion of fine and coarse particles, and subsequently causing said mass to slowly move downwardly while subjecting it to a uniform carbonizing heat free from disturbing movement or forces which would tend to dissociate the fine and coarser particles, whereby the carbonization is carried on without mass caking to produce a residue of coke dust.

6. A process of producing coke in a powdered state which consists in subjecting pulverized caking coal made up of fine particles and coarser particles, with a sufficient proportion of fine particles to ultimately insulate the coarser particles from caking together, to an oxidizing treatment non-productive of appreciable combustion and in the presence of an oxygen-containing gas, collecting the oxidized coal as a substantially static mass and in substantially the original proportion of fine and coarse particles, and subsequently causing said mass to slowly move downwardly while subjecting it to a uniform carbonizing heat free from disturbing movement or forces which would tend to dissociate the fine and coarser particles, whereby the carbonization is carried on without mass caking to produce a residue of coke dust.

7. A process of producing coke in a powdered state which consists in subjecting pulverized caking coal made up of fine particles and coarser particles, with a sufficient proportion of fine particles to ultimately insulate the coarser particles from caking together, to an oxidizing treatment non-productive of appreciable combustion and in the presence of an oxygen-containing gas, collecting the oxidized coal as a substantially static mass and in substantially the original proportion of fine and coarse particles, and subsequently causing said mass to slowly move downwardly while subjecting it to a uniform carbonizing heat free from disturbing movement or forces which would tend to dissociate the fine and coarser particles, whereby the carbonization is carried on without mass caking to produce a residue of coke dust.

8. A process of producing coke in a powdered state which consists in subjecting pulverized caking coal made up of fine particles and coarser particles, with a sufficient proportion of fine particles to ultimately insulate the coarser particles from caking together, to an oxidizing treatment non-productive of appreciable combustion and in the presence of an oxygen-containing gas, collecting the oxidized coal as a substantially static mass and in substantially the original proportion of fine and coarse particles, and subsequently causing said mass to slowly move downwardly while subjecting it to a uniform carbonizing heat free from disturbing movement or forces which would tend to dissociate the fine and coarser particles, whereby the carbonization is carried on without mass caking to produce a residue of coke dust.

9. A process of producing coke in a powdered state which consists in subjecting pulverized caking coal made up of fine particles and coarser particles, with a sufficient proportion of fine particles to ultimately insulate the coarser particles from caking together, to an oxidizing treatment non-productive of appreciable combustion and in the presence of an oxygen-containing gas, collecting the oxidized coal as a substantially static mass and in substantially the original proportion of fine and coarse particles, and subsequently causing said mass to slowly move downwardly while subjecting it to a uniform carbonizing heat free from disturbing movement or forces which would tend to dissociate the fine and coarser particles, whereby the carbonization is carried on without mass caking to produce a residue of coke dust.
in subjecting said pulverized coal to an oxidation treatment wherein the coal particles are passed through an oxygen-containing heating gas with the natural gravitation of the coarser particles retarded, without loss of substantially completely oxidize that portion of the smaller particles requisite in a collected mixture, to separate and isolate the remaining larger particles therein and to thereby render the entire mixture non-caking in character, collecting the oxidized coal as a substantially static mass and in substantially the original proportion of fine and coarse particles, and finally causing said mass to slowly move downwardly while subjecting it to a substantially uniform carbonizing heat free from disturbing movement or forces which would tend to dissociate the fine and coarser particles, whereby the carbonization is carried on without mass caking to produce a residue of coke dust.

10. A process of producing coke in a powdered state from caking coal which has been pulverized to provide particles of graduated size ranging from fine to coarse particles, which consists in subjecting said pulverized coal to an oxidation treatment wherein the coal particles are passed through an oxygen-containing heating gas with the natural gravitation of the coarser particles retarded and without any substantial loss of fine particles, the oxidation treatment being for a period sufficient to substantially completely oxidize that portion of the smaller particles requisite in a collected mixture, to separate and isolate the remaining larger particles therein and to thereby render the entire mixture non-caking in character, collecting the oxidized coal as a substantially static mass and in substantially the original proportion of fine and coarse particles, and finally causing said mass to slowly move downwardly while subjecting it to a substantially uniform carbonizing heat free from disturbing movement or forces which would tend to dissociate the fine and coarser particles, whereby the carbonization is carried on without loss of fine particles of the mixture and without mass caking to directly produce a residue of coke dust.

11. The process of producing powdered coke from caking coal which has been pulverized to provide particles of graduated size ranging from fine to coarse particles, which consists in subjecting said pulverized coal to an oxidation treatment in contact with an oxygen-containing gas for a period sufficient to substantially completely oxidize that portion of the smaller particles requisite in a collected mixture, to separate and isolate the remaining larger particles therein and to thereby render the entire mixture non-caking in character, collecting the oxidized coal as a substantially static mass and in substantially the original proportion of fine and coarse particles, and finally causing said mass to slowly move downwardly while subjecting it to a substantially uniform carbonizing heat free from disturbing movement or forces which would tend to dissociate the fine and coarser particles, whereby the carbonization is carried on without mass caking to produce a residue of coke dust and distilled gases, and causing the distilled gases to pass upwardly through said mass to heat the mass by convection and then withdrawing the distilled gases from the space above the mass.

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