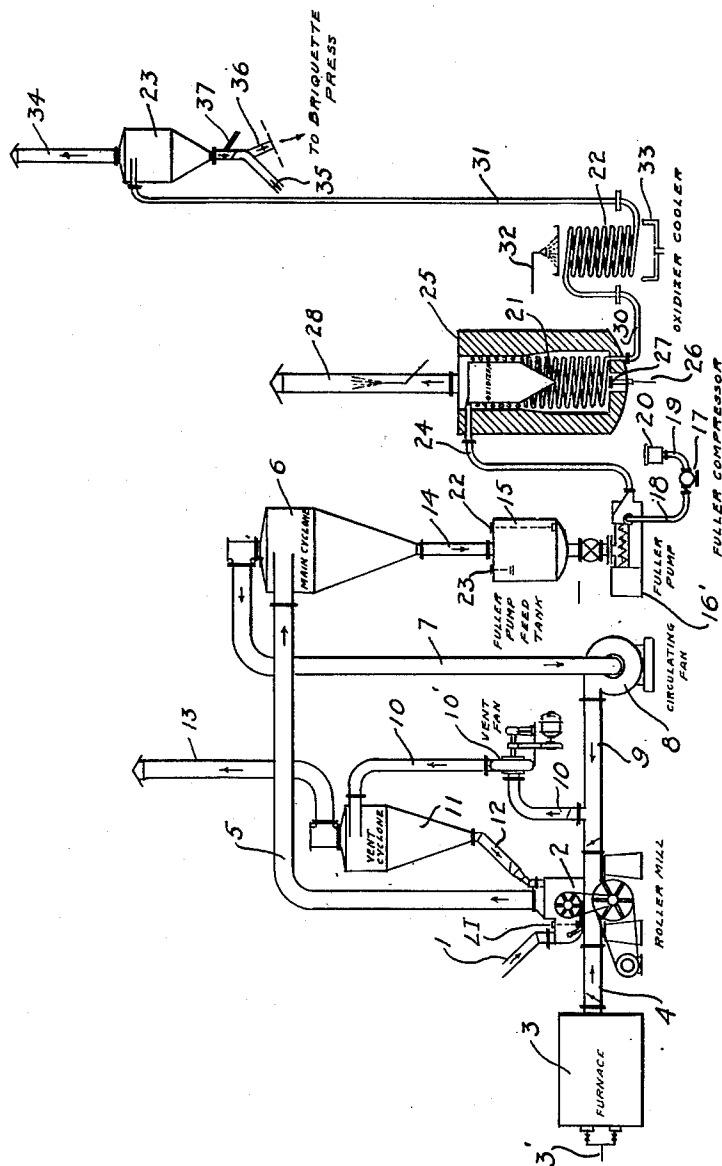


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PROCESS OF TREATING COAL

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PROCESS OF TREATING COAL

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This invention relates to an improved method of treating swelling and caking coals to desirably modify their coking characteristics.

As is known, the metallurgical coke utilized in this country is largely produced in by-product coke ovens by high temperature distillation of selected grades of bituminous coals. The physical structure of the ovens used to effect such distillation is such as to restrict the charge material to certain types of coals, e. e., to bituminous coals which have satisfactory coking properties but do not unduly swell.

There are many bituminous coals that swell badly which might otherwise be suitable for the production of metallurgical coke and other products such as partially coked fuel briquettes. It has long been known that weathering decreases the swelling power of bituminous coals and it has been proposed to reduce the swelling and caking characteristics of such coals by oxidation. Such an oxidation of coal must be carefully controlled so that the coal when carbonized will have sufficient coking power to cohere firmly during carbonization. The coking power of a coal can be practically completely destroyed by over oxidation.

The methods heretofore proposed for oxidizing bituminous coals to reduce the tendency to unduly swell generally involve a treatment at low temperatures for prolonged periods of time as, for example, at a temperature of the order of 150° C. for a period of the order of from 24 to about 120 hours depending on the type of coal. Such a protracted period of treatment has many obvious disadvantages not the least of which is the excessive storage capacity that is necessarily required to contain the coal during such treatment. Suggestions have been advanced as to methods for shortening the oxidation treatment, such, for example, as effecting the oxidation under superatmospheric pressure of the order of 50 pounds to 150 pounds p. s. i. at temperatures of the order of 115° C. to about 200° C. or by subjecting heated coal alternately to pressure and vacuum. Such methods still entail a treating period of several hours and present the disadvantage of requiring expensive pressure tight storage equipment. In general then it had always been assumed by workers in the field that preconditioning a swelling coal to modify its caking and swelling properties required a relatively prolonged oxidation of the coal.

As a result of extensive research and study of this problem, it has been ascertained that the swelling and caking properties of swelling bituminous coals may be modified to render such coals amenable to subsequent coking by an improved method which involves a novel concept of approach to the problem. Boardly considered, the invention is based upon the concept of effecting the oxidation at high temperatures for but a brief interval of time and without employing expensive and extensive equipment or specially selected or controlled atmosphere. As will be seen more fully hereinafter, the improved process comprises in effect a flash oxidation of fluidized coal in

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ordinary air at elevated temperatures of the order of 500° F. to 750° F. and above, followed by quick cooling of the heated coal. In another aspect, as compared to previously entertained concepts, the present invention might be defined as a superheated preconditioning of swelling coal.

It will be appreciated that by utilizing such a concept numerous advantages accrue. Since the thermal treatment is for but a brief interval of time, i. e. since the retention period of the coal in the heating apparatus is extremely short, a very large output of coal for a relatively small amount of equipment is insured. Using this method of flash oxidation and quick cooling eliminates the costly pressure storage equipment required by earlier proposed methods. As will be pointed out later, this method also insures other advantages which are as desirable as they are unexpected and unpredictable. The novel treatment to be described not only desirably modifies the caking and swelling properties of the coal, but also, with most types of coal, unexpectedly lowers the sulfur content of the oxidized coal and the sulfur content of coke made from such oxidized coal. Furthermore, an additional phenomenon takes place during the treatment which is difficult to explain, but nevertheless obtains, the effect of which is to lower the ash content of the treated coal.

The present invention is particularly useful for preconditioning coal which is to be briquetted and carbonized according to processes described in prior patents such as 2,131,702 and 2,314,641. As will be appreciated, the present invention is of general utility for modifying the caking and swelling characteristics and/or for reducing the sulfur and ash content of such coals whatever may be the uses to which such coals are put.

The invention can be more readily comprehended, and its effectiveness evaluated by a consideration of the operation in the apparatus as illustrated in the single figure of the accompanying drawing.

Generally considered, the sequential steps of the process comprise; crushing and drying the coal, flash oxidizing the coal, preferably in the form of a high velocity fluidized stream at considerably elevated temperatures and for but a brief interval and then quickly and positively cooling the oxidized coal. These operations may be carried out in a continuous operation utilizing readily available standard equipment to produce the novel processed coking coal.

The bituminous coals which are to be treated and benefited by the process or selected blends or mixtures of such coal are preferably dried and pulverized prior to the special oxidizing treatment. It has been found that the presence of water vapor in the oxidizing gas tends to retard or inhibit the oxidation of the coal and for this reason it is desirable to dry the coal to less than one percent of free moisture.

While the particle size of the coal is not critical, it is an important factor in the operation. It is advisable to grind or pulverize the coal so that 100% is minus 20 mesh and at least 90% is minus 28 mesh. It has been ascertained that if the coal particles are too large, i. e., substantially over about 20 mesh, it is somewhat more difficult to oxidize and the time required for oxidation is increased. If the preconditioned coal is to be briquetted the particle size is of additional importance. Larger coal particles tend to impart a sandy texture to the subsequently formed raw briquette and to reduce the abrasion strength. It has been determined from experience that during carbonization briquettes formed from pulverized coal of substantially minus 20 mesh can in general be heated through the critical range at a higher rate of temperature rise than briquettes comprised of larger coal particles. This critical range, which extends from approximately 350° C. to

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about 500° C. is that range in which fusion or incipient fusion of the coal takes place and in which upon evolution of volatile matter the coal mass resolidifies. If the temperature rise within this range is too rapid the briquettes become distorted and tend to adhere to each other. Such an unduly rapid heating in this range also tends to reduce the head load strength of the briquettes.

In carrying out the process, the coal or blend to be treated is taken from a storage bin (not shown) and is charged by way of conduit 1 to any suitable pulverizing unit shown illustratively as the roller mill 2 provided with a suitable level indicator L1. In lieu of a roller mill, any other suitable pulverizing equipment may be employed such as a hammer mill, fluid attrition mill, ball mill or the like.

In the illustrative embodiment the coal pulverized in the mill 2 is picked up by a stream of hot gas, such as hot air admitted from the furnace 3 through the valve controlled conduit 4. The furnace may be of any desired type and may, for example, be a gas fired furnace fed with fuel gas through feed line 3'. The temperature in the pulverizer may be controlled by proper adjustment of the valve in line 4. As will be observed, the mill is connected in the fluid circuit which includes the discharge conduit 5, cyclone separator 6, and recycle conduit 7, circulating fan 8 and recycle conduit 9. As will be appreciated, when the unit is on stream the fine coal particles, i. e., those less than about 20 mesh are picked up by the hot air stream, forced by fan 8 through the conduit 9 and into the pulverizing mill. The oversize coal particles dropping out of this circulating stream are retained in and are further triturated in the mill. The air stream laden with the classified finer particles passes through line 5 to the cyclone or equivalent separator 6 in which most of the suspended coal particles are separated and the hot air largely freed of coal is again recycled through this circuit.

As shown, a vent circuit is connected into the described recirculation circuit. This includes the valve controlled line 10 having the interposed vent fan 10', the connected vent cyclone separator 11, the valve controlled solids return line 12, and vent line 13 which discharges to atmosphere. The operation of this vent circuit is readily apparent. The positively driven vent fan 10' removes air from the main recirculating circuit in amounts controlled by the valve in line 10 and discharges this air into fluid-solids separator 11. In this separator the residual coal is separated and returned to the pulverizing mill 2 through the line 12 while the waste air is discharged from the system through vent line 13. As will be appreciated during operation the vent circuit is so controlled as to discharge a quantity of air equal to that admitted to the circuit from the furnace 3 in addition to water vapor produced from surface moisture and water of constitution in the coal.

The above described first phase of the operation, as will be appreciated, produces a suitably ground and dried coal. This hot coal as explained collects in the cyclone or equivalent separator 6 and is fed from the cyclone to the flash oxidation zone. As shown the cyclone 6 is provided with the solids discharge line 14 which discharges the dried coal to a suitable apparatus in which the coal is fluidized prior to passage through the oxidizing zone. Such fluidizing may be effected in any desired manner and by any suitable mechanism. In the embodiment chosen for illustration, this is effected by means of conventional apparatus such as a Fuller-Kinyon pump unit. As illustrated, the coal from the cyclone 6 is discharged into a feed tank 15 which desirably is provided with the level indicators 22 and 23 and also with a pressure indicator not shown. This tank should also be provided with a separate draw-off line at the bottom so that samples of the coal may be withdrawn for any current checks that may be desired.

The hot coal is fed continuously from the feed tank 15 to

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the fluidizing pump 16 through a suitable valve connection such as the rotary vane valve 16'. As will be appreciated, the coal fed to the pump 16 is aerated and fluidized by air forced into the pump by the air compressor 17 through line 18. As shown the air intake line 19 of the compressor is preferably provided with the air filter 20. In the typical operation the quantity of air required for proper aeration and consequent fluidizing of the coal may vary somewhat. In operations which have been conducted effective oxidizing has been achieved using eight pounds of coal per pound of air; higher ratios, i. e., of the order of 12 to 15 pounds of coal per pound of air may desirably be employed. The fluidized coal is forced in a continuous stream through the oxidizing zone 21 and the cooling zone 22 after which the suspended oxidized coal is separated from the carrier air in a suitable fluid-solids separator such as the cyclone 23.

The described unit, as will be understood, is provided with suitable appropriately located instruments (not shown) to indicate and record the temperature, pressure and rate of flow during the operation.

As indicated on the drawings, the flash oxidation treatment can conveniently be carried out by passing the fluidized coal through a continuous coil wherein it is raised to the desired temperature and thence continuously through a cooling coil. The fluidized coal passes from pump 16 through the line 24 and the oxidizer coil 21 located in the combustion zone of furnace 25. The furnace may be of any desired type, such as a gas or oil fired furnace, the fuel for which is fed through line 26 to the burner 27. The flue gas from the furnace as shown passes out through the stack 28.

The high heated stream of coal then passes through transfer line 30 to the upper portion of the cooling coil 22 and then flows through line 31 to the cyclone separator. The hot fluid stream is quenched during passage through coil 22 in any suitable manner as by means of a water spray fed through line 32, by immersion in a tank of a coolant or by any other equivalent method. The water used for cooling, as shown, is collected in the tank 33 from which it may be continuously or periodically withdrawn.

The operation of the process and the general characteristics of the apparatus can be more readily understood from a consideration of a typical operation of a unit such as has been described. In such a unit having a capacity of 13 tons of coal an hour, the oxidizer coil 21 comprises approximately 600 linear feet of pipe, preferably of 6 inch diameter and the cooling coil 22 is of the same size and length. In operation the pressure on the stream at the exit of the pump 16 may be between 20 and 25 p. s. i. In such typical operation the temperature of the air passing from furnace 3 to the pulverizer is controlled at about 500° F. and the furnace 25 is operated so as to raise the temperature of the coal to between about 675° F. to about 800° F. and preferably between 700° F. to 750° F. In these circumstances the actual velocity of the coal stream at the discharge of pump 16 is from 1200 to 2000 or more feet per minute and in an oxidizer coil of the dimensions given the retention period of the coal in such coil is only about 10 or 15 seconds. During passage through the oxidizer coil the pressure progressively drops and is reduced to substantially zero pressure at the cyclone.

The cooler is operated so as to quickly reduce the temperature down to the lowest convenient value. Inasmuch as the carrier air stream contains water vapor evolved at the elevated temperatures from surface moisture and/or partial decomposition of the coal, it is advisable to avoid cooling down to a temperature which would cause condensation of such water vapor. In actual operation it has been found satisfactory to control the cooler so as to insure an exit temperature of about 150 F. and particularly if the oxidized coal is to be used immediately for producing briquettes.

The cooled stream of particulated coal, as noted pre-

viously, is continuously discharged from the cooler through line 31 to cyclone 23 in which the coal particles are separated from the air and water vapor which latter are vented to atmosphere through the stack 34. The cooled oxidized coal particles separated in the cyclone may be drawn off through line 35 to storage or alternately through line 36 to be fed to a briquetting unit. Samples for periodic check tests may be withdrawn through sampling line 37.

It will have been appreciated that the improved method of preconditioning bituminous coal to alter its swelling and caking properties essentially involves extremely rapid or flash oxidation at very considerably elevated temperatures followed immediately by a rapid or quick quench to check any further oxidation. As incident preliminary steps, as explained, the coal to be treated is reduced to a predetermined particle size range and is dried to a low moisture content. The apparatus shown in the drawing is designed and has been found to operate effectively to produce the results desired. It is obvious that other and specifically different types of apparatus may be employed which in the process are functionally equivalent to the particular units shown for illustration and explanation. Thus while the illustrative embodiment of the invention involves a particular pulverizing and drying circuit in which the coal is pulverized in an atmosphere of drying gas, it is apparent that the same results may be achieved by specifically different methods and utilizing apparatus other than that shown. Thus, for example, the raw coal may preliminarily be crushed in any suitable crushing apparatus down to about 1/4 inch, dried in any suitable drying unit such as a rotary kiln dryer and then fed to a pulverizing mill which may or may not be air swept. These or similar modifications which insure the production of a dried, suitably particulated coal are considered to be comprehended within the spirit of the invention.

As indicated previously, the novel preconditioning treatment of the invention modifies the coal in a manner rendering it particularly valuable for the production of coke. The rationale of this modification is difficult to explain but the ultimate effect is that with the exception of certain specific types of coal, the coke made from coal

It was similarly determined that coke made from the oxidized coal, in all cases shows less ash content than coke made by the same procedure from the same coal which was not preliminarily oxidized.

These facts were established by a series of laboratory tests and pilot plant operations, the general results of which are indicated below.

In the following tables the results of laboratory tests on the indicated coals, and a blend of the five coals are recorded. The several samples of coal were pulverized to 100% minus 28 mesh and at least 50% minus 100 mesh. Samples of the several pulverized coals were heated on a hot plate with constant agitation and as the oxidation proceeded buttons were made at short intervals. When the desired coherent, non-swollen button was obtained, the coal sample was cooled with continuous agitation. The time required for the oxidation of the different coals is shown in Table I, as is known, a general indication of the ease of oxidation of the coal.

TABLE I

	Time on Hot Plate, Minutes	Coal Classification
Heisley.....	15	Low Volatile.
Revloc.....	15	Do.
Johnstown #72.....	15	Do.
Marion #41.....	20	High Volatile (38% VM).
Golden Ridge.....	24	High Volatile (32% VM).
5 Coal Blend (20% of each).....	16	

Water bound briquettes were made from each of the coals both in the raw and oxidized state. These briquettes were carbonized in a laboratory head load tester rapidly raising the temperature up to about 350° C. and continuing the heating at a controlled rate of 2.5° C. temperature rise per minute between 350° C. and 500° C. and were held at a finishing temperature of 800° C. for one-half hour.

The proximate and sulfur analysis of the test samples are shown below in Table II. The amounts of sulfur removed during carbonization of the raw coals and same coals in oxidized condition are shown in Table III.

TABLE II

Analyses of coals and cokes produced

	Raw Coal			Oxidized Coal			Coked Raw Coal ¹			Coked Oxidized Coal ¹		
	VM	Ash	Sul.	VM	Ash	Sul.	VM	Ash	Sul.	VM	Ash	Sul.
(1) Heisley.....	18.35	6.25	1.31	18.18	6.28	1.24	0.79	7.91	1.00	0.60	7.65	0.96
(2) Revloc.....	19.52	7.90	1.13	19.30	7.94	1.11	0.71	10.28	0.93	0.58	9.89	0.85
(3) Johnstown #72.....	20.86	7.78	1.26	19.81	7.91	1.36	0.59	10.02	0.98	0.34	9.56	0.88
(4) Marion #41.....	38.43	8.25	0.96	34.57	8.49	1.00	1.14	13.81	0.85	0.91	12.71	1.88
(5) Golden Ridge.....	31.86	3.07	0.60	28.77	3.21	0.62	0.50	4.69	0.58	0.73	4.47	0.56
(6) Blend (20% Each).....	25.45	6.80	1.06	24.16	6.84	1.03	0.43	9.85	0.89	0.80	8.73	0.96
Weighted Avg. of 5 Coals.....	25.80	6.65	1.05	24.12	7.77	1.07	0.74	9.27	0.88	0.63	8.81	1.00

¹ Briquettes made with no binder and coked in gas stream at 2.5° C. per minute between 350 and 500° C. and held at 800° C. for 30 minutes.

oxidized according to the invention displays a higher sulfur removal than coke made under the same conditions from such coal which had not been oxidized. As will be apprehended, this is of profound significance because the presence of sulfur in the coke is detrimental; especially for coke destined for blast furnace use where it costs about twenty-five cents to remove each tenth of a percent. of sulfur in the coke, such cost being represented by the extra coke and limestone necessitated.

In the course of investigation and study of the effects of the described flash oxidation treatment on different types of bituminous coals and various blends of such coals it was ascertained that with some notable exceptions coke made by briquetting and carbonizing coal oxidized as described hereinbefore, displayed a significantly higher sulfur removal than the same coal which was not pre-oxidized.

TABLE III

Total sulfur removed during oxidation and carbonization ¹

Coal	Oxidized Coal	Coked Raw Coal	Coked Oxidized Coal
	Percent	Percent	Percent
Heisley.....	5.34	37.10	39.69
Revloc.....	1.77	33.19	39.03
Johnstown #72.....	7.14	38.02	44.52
(Gain)	0		
Marion #41.....	0	44.48	22.40
(Gain)			
Golden Ridge.....	0	33.67	35.67
Blend (20% of Each).....	3.77	37.08	31.79
Weighted Average of 5 Coals.....	0	37.33	28.86

¹ Sulfur contents are compared on the common basis of pounds per hundred pounds of raw coal.

From a study of Tables II and III, it is apparent that all of the individual coals with the exception of Marion #41 displayed a greater removal of sulfur in the carbonization of the oxidized coal than of the raw coal. Marion #41 conversely showed an actual pick-up or gain in sulfur over what was originally present in the coal. It would appear that this increase is probably attributable to the pickup of hydrogen sulfide from the sour gas which passes around the briquettes during the carbonization. This sulfur pickup is also reflected in blends in which Marion #41 is incorporated.

It is particularly to be observed that there is a significantly low ash content in the coked oxidized coal as compared to the coked unoxidized coal.

It has been found that in actual large scale plant operation the reduction in sulfur retention and the lowering of the ash content are accentuated and display substantial quantitative differences. These differences are illustrated in the results recorded in Table IV. In this table are recorded the results of operation in a commercial unit in which coal blends were flash oxidized and quenched according to the present invention and the oxidized coal was briquetted using a sulfuric acid-treated coal tar pitch as the binder for the treated coal according to the Wolf Patent 2,314,641, using approximately 11% of binder material. The briquettes were carbonized in a vertical retort having a daily capacity of about one hundred tons of raw briquettes under the conditions described in the prior patent to Berry, 2,131,702. The results recorded in Table IV represent the analysis of composite samples of the indicated one day's and five days' runs.

TABLE IV

Typical analyses of solid materials

COMPOSITE SAMPLES OF ONE DAY'S RUN—FIN. TEMP. COKE 830° C.

	Raw Coal	Pulv. Coal Grab Sample	Oxid. Coal	Raw Briq't	Coke
Vol. Matter (Dry).....	18.39	18.13	17.67	24.39	0.75
Fixed Carbon.....	74.85	75.57	77.05	69.92	91.97
Ash.....	6.76	6.10	5.28	5.69	7.28
Sulfur.....	1.40	1.23	0.95	1.31	1.04

COMPOSITES—FIVE DAYS' RUN

	Raw Coal	Pulv. Coal Grab Sample	Oxid. Coal	Raw Briq't	Coke
Vol. Matter (Dry).....	18.41	18.02	17.50	24.12	0.89
Fixed Carbon.....	74.75	74.68	77.02	70.46	92.85
Ash.....	6.84	7.30	5.48	5.42	6.86
Sulfur.....	1.58	1.65	1.26	1.53	1.03

It is to be observed that the raw briquettes designated in the tables contain 11% binder which latter contains approximately 10% of sulfuric acid. It has been ascertained as a result of numerous tests using this binder with inert aggregates such as sand that upon carbonization about 70% of this binder is recovered as a liquid tar product and the remainder as coke. Since oxidized coal is 17.67% volatile material, the raw briquette volatile material may readily be calculated on the assumption of 11% of binder as follows:

$$.1767 \times 89 = 15.7$$

$$0.70 \times 11 = 7.7$$

23.4% estimated volatile material of raw briquette

This, as will be observed, is in close agreement with the 24.39% volatile material actually determined.

It will be noted that the same calculation on the second set of data (composites of five days' run) gives a theoretical volatile material content of 23.3 as against an actual of 24.12. This difference may likely be due to the relatively greater binder loss incident to running a

volatile matter test as compared to the relatively slow carbonization rate of the briquettes.

A study of the data recorded in Table IV reveals the striking effects of the flash oxidation treatment on the ash and sulfur contents of the oxidized coal and finished coke. As will be seen, the ash and sulfur content of the oxidized coal is significantly lower than that of the raw coal and grab samples. It is also interesting to observe that the softening temperature of the ash in the oxidized coal is measurably higher than the raw coal, for example, whereas the softening temperature of the ash of raw Heasley coal is 2320° F., the softening temperature of Heasley coal oxidized according to the present procedure is 2570° F. while that of coked briquettes made from the oxidized coal is 2520° F.

This appreciable reduction of ash and sulfur content effected in the process is difficult to explain. The reduction in ash content may possibly be due in some degree to a type of winnowing effect taking place in the turbulent fluidized stream of the particulated coal or conceivably to a chemical conversion of some of the ash-forming constituents to relative volatile compounds such as metal carbonyls which separate from the solid phase coal. Similarly, the mechanism of action or reaction which results in sulfur removal is obscure and has not been satisfactorily postulated or explained. However, whatever the mechanism of such removal may be, it is found as a demonstrable fact that preconditioning the coal in accordance with the described flash oxidation treatment does reduce the ash and sulfur content in the oxidized coal and this reduction is similarly reflected in the finished coke.

As previously explained, the processed coal may be employed mediately or immediately for any use to which its imparted characteristics of reduced swelling or lowered ash and sulfur content adapts it. Such preconditioned coal may be briquetted with a suitable binder such as a sulfuric acid treated tar binder, and carbonized in a continuous retort to produce an excellent grade of metallurgical coke and large yields of primary tars. The preconditioned coal produced as described herein may be utilized in smelting operations, as for example, by associating it with metal ores, such as zinc ores, to form briquettes which may be carbonized to thereby produce a strong briquette, containing distillable zinc or other metal, which briquette will not materially disintegrate during subsequent smelting. The processed coal may also be briquetted using any suitable binder, and then distilled to the desired extent to produce a fuel briquette having the general characteristics of anthracite.

While the invention has been described through the medium of a presently preferred embodiment, it is to be understood that this is given to illustrate the fundamental principles involved, namely the concept of a rapid or flash high temperature oxidation of swelling and caking coals to improve the coal in the several characteristics mentioned and not as limiting the useful scope of the invention to the described illustrative embodiment. Manifestly a number of mechanically different but functionally equivalent units of apparatus other than those described in the illustrative embodiment may be utilized.

We claim:

1. A method of treating swelling and caking coals by controlled oxidation to reduce such swelling and caking properties which comprises pulverizing and drying the coal to less than 1% free moisture content then subjecting the coal in a streaming entrainment in an oxidizing gas to oxidation at a temperature above about 500° F. for a brief period of time and then rapidly cooling the oxidized coal by indirect heat exchange while in such streaming entrainment.

2. A method of treating swelling and caking coals by controlled oxidation to reduce such swelling and caking properties which comprises subjecting the coal in pulverized form containing approximately 1% of surface

moisture and suspended in a carrier stream of an oxidizing gas to a flash oxidation at a temperature between about 675° F. and 800° F. for less than one minute and then quickly cooling the oxidized coal while suspended in the carrier gas by indirect heat exchange to inhibit further oxidation of the coal.

3. A method of treating swelling and caking coals by controlled oxidation to reduce such swelling and caking properties which comprises subjecting the coal in pulverized and suspended form having a moisture content of less than one percent to a flash oxidation for a period of less than about one minute at a temperature of between about 675° F. and 800° F. and then quickly cooling the oxidized coal while in suspended form by indirect heat exchange to inhibit further oxidation of the coal.

4. A method of treating swelling and caking coals by controlled oxidation to reduce such swelling and caking properties which comprises suspending pulverized, predried coal to a moisture content of less than 1% in a stream of air, heating this suspended coal at a temperature of between about 675° F. and 800° F. for a period of less than a minute and then quickly cooling the suspended coal by indirect heat exchange to inhibit further oxidation of the coal.

5. A method of treating swelling and caking coals by controlled oxidation to reduce such swelling and caking properties which comprises pulverizing and drying coal to a moisture content of less than 1%; suspending the pulverized dried coal in a stream of air, heating the suspended coal at a temperature of between about 675° F. and 800° F. for less than one minute and then quickly cooling the coal while in said stream of air.

6. A method of treating swelling and caking coals by controlled oxidation to reduce such swelling and caking properties and to lower the ash content which comprises pulverizing and drying the coal to a free moisture content of less than 1%, suspending the pulverized dried coal in a stream of air, rapidly passing the suspended coal through a continuous coil and heating the suspended stream to a temperature of between about 675° F. and 800° F. for less than about one minute, then passing the coal to a connected continuous coil and rapidly cooling the suspended coal therein by indirect cooling and separating the particulate oxidized coal from the fluid carrier.

7. A method of treating bituminous coal by controlled oxidation to reduce the ash content and to modify the swelling and caking properties which comprises pulverizing and drying the coal to a free moisture content of less than 1%, suspending the coal in an air stream, continuously passing the air stream at an initial cold air velocity of between about 1200 and 2000 feet per minute through a heating zone and thence through a cooling zone, raising the temperature of the suspended stream in the heating zone to between about 675° F. and 800° F., retaining the suspended stream in such heating zone for a period of less than one minute and then quickly cooling the fluidized stream in said cooling zone by indirect cooling.

8. A method according to claim 7 in which the pulverized coal is dried to a moisture content of less than 1%.

9. A method of treating swelling and caking coals by controlled oxidation to reduce the swelling and caking properties which comprises pulverizing and drying coal in a stream of hot gas to reduce the moisture content of the coal to less than 1%, separating the dried coal from the gas, suspending the dried coal in a stream of air, continuously passing the suspended stream at substantial velocity through an elongated passageway, heating the suspended stream in one portion of the passageway to a temperature of between about 675° F. and 800° F. within a brief interval of less than one minute, immediately cooling the suspended stream in the adjacent portion of the passageway in a brief interval of time by indirect heat ex-

change to inhibit further oxidation and separating the oxidized coal from the fluid carrier.

10. A method of treating swelling and caking coals by controlled oxidation to reduce the swelling and caking properties which comprises pulverizing and drying coal down to a moisture content of less than 1%, suspending the dried coal in a stream of an oxidizing gas, passing the suspended stream through an elongated narrow passageway rapidly heating the stream in one portion of the passageway to a temperature of between about 675° F. and 800° F., then immediately indirectly cooling the suspended stream in the adjoining portion of the passageway to a temperature sufficient to check the oxidation reaction and separating the substantially undevolatilized oxidized cooled coal from the fluid vehicle.

11. A process in accordance with claim 10 in which the retention period of the suspended stream in the heated portion of the passageway is less than one minute.

12. A process in accordance with claim 10 in which the velocity of the suspended stream entering the passageway is above 1000 feet per minute.

13. A process in accordance with claim 10 in which the velocity of the suspended stream entering the passageway is above 1000 feet per minute and the retention period within the heated portion of the passageway is less than 30 seconds.

14. A process in accordance with claim 10 in which the coal is pulverized to 100% minus 20 mesh.

15. A method of coking badly swelling and caking coals which comprises pulverizing and drying the coals down to a moisture content of less than 1%, continuously suspending the dried coal in an air stream, passing the suspended stream through an elongated narrow passageway, rapidly heating the stream in one section of the passageway to a temperature of between about 670° F. and 800° F. and then immediately cooling the stream by indirect cooling down to a temperature sufficient to check the oxidation reaction, separating the cooled coal from the fluid carrier, briquetting the oxidized coal and converting the briquetted coal into coke by carbonizing in a stream of hot tar-denuded gases derived from the distillation of the briquettes.

16. The treatment of coals, which because of intrinsically excessive swelling and caking properties are not directly suitable for the production of sound coke products, to render such coals readily amenable to subsequent coking for the production of sound, dense, coke-like bodies which treatment comprises, subjecting a confined streaming entrainment of such coals in particulated form in a gaseous oxidizing medium in gaseous suspension to flash oxidation at a temperature in the range of from about 675° F. to 800° F. and for a period of less than one minute and then immediately, drastically quenching the confined streaming entrainment by indirect heat exchange down to a temperature at which active oxidation is prevented.

17. A method of treating swelling and caking coals by controlled oxidation to render such coals amenable to subsequent coking which comprises, subjecting the coal in pulverized form, having a free moisture content of less than 1%, in a streaming entrainment of such pulverulent coal to a flash oxidation, for a period of less than about a minute, at temperatures above about 500° F. and within the plastic range of the coal, quickly cooling the coal while in such streaming entrainment by indirect heat exchange to inhibit further oxidation of the coal, and recovering particulated substantially unagglomerated oxidized coal.

18. A method of treating swelling and caking coals by controlled oxidation to render such coals amenable to subsequent coking which comprises, pulverizing and drying the coal to reduce the free moisture content to less than approximately 1% and then subjecting the coal suspended in a stream of a carrier oxidizing gas to a flash

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oxidation at a temperature above about 500° F. and with-
in the plastic range of the coal and for a period of less
than about a minute, quickly quenching the coal, while
in suspension in the carrier stream, by indirect cooling and
recovering particulated, substantially unagglomerated 5
oxidized coal.

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