[54] **UPGRADING COKING COALS AND COKE PRODUCTION**

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[57]   **ABSTRACT**

In coke production, coal fines are agglomerated by adding a liquid hydrocarbon to an aqueous dispersion of the fines and agitating the mixture to form spherical agglomerates. These agglomerates are separated, dried, preheated and carbonized.

9 Claims, 1 Drawing Figure

14×0 MESH COAL IN
WATER SUSPENSION
10-40 % w/w

MINERAL
SEPARATOR

FROTH
FLOTATION
CELLS

AGITATOR

SCREENER

HYDROPHILIC MINERAL
MATTER & WATER.

TAR BINDER

DRYER

PREHEATER

SLOT TYPE
COKE OVEN
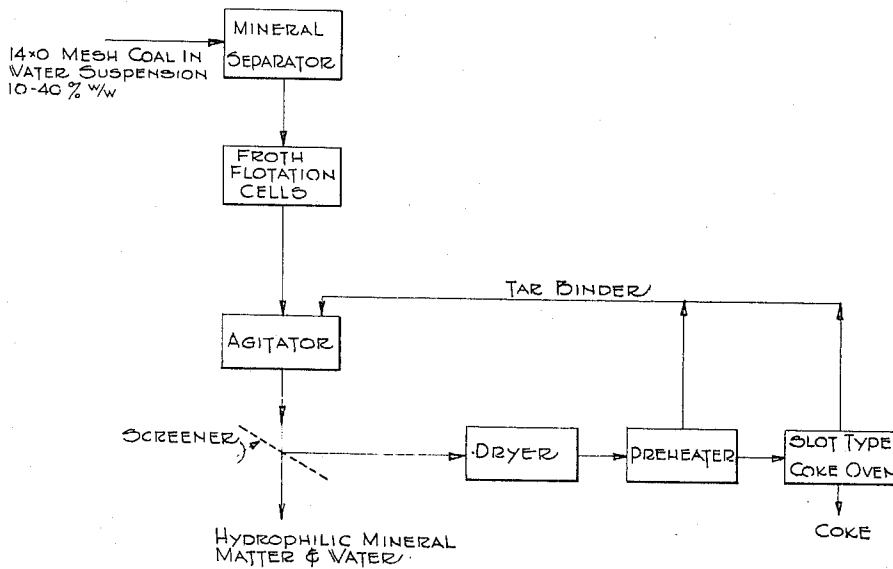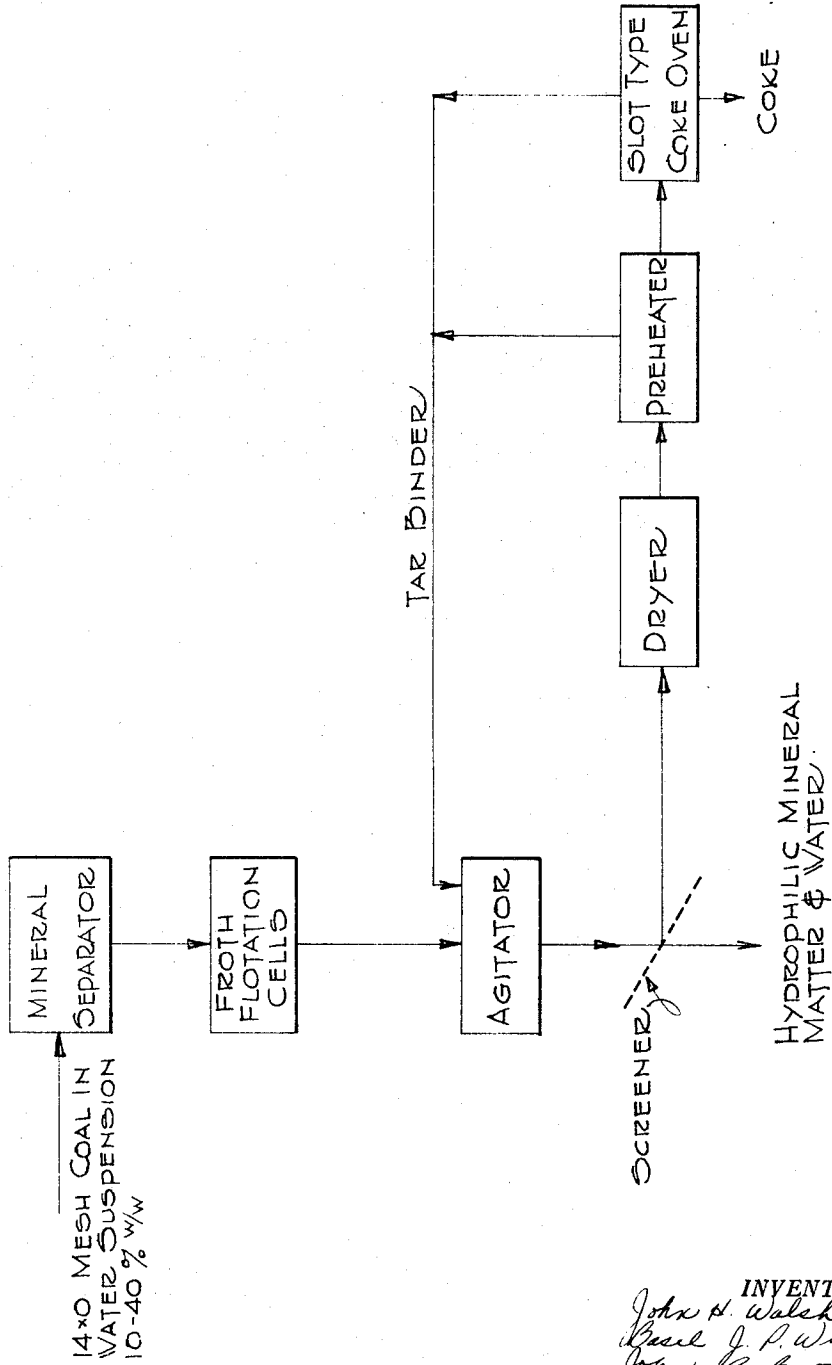
COKE

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UPGRADING COKING COALS AND COKE PRODUCTION

The invention seeks to provide an effective and safe preheating process to produce coke of low sulphur and ash contents and to increase the output of conventional coke ovens.

In the production of coke in the conventional vertical slot coke oven, there are two well-recognized problems to which this invention seeks a solution, namely, (1) the difficulty in producing coke of desirably low ash and sulphur content, and (2) the difficulty in providing a satisfactory preheating step (a step which has productivity advantages) which can be conducted in an efficient and safe manner.

With particular regard to the first problem, it will be recognized that the major problem in upgrading coal, as compared to other minerals, is that in the latter case only a minor portion of raw substance to be treated is desired as end product; for coal, on the other hand, nearly all the raw substance treated is desirable and the waste material constitutes only a minor fraction of the feed. It is evident then that all so-called coal-cleaning procedures must recover a high proportion of raw coal to be economical. However, the present invention is of value not only for the treatment of raw coal but also in the recovery of high-grade coal from the middle products obtained as a consequence of conventional coal-cleaning operations. Physical separation processes can only remove that proportion of sulphur held in association with those minerals distinct from the coal substance. Commonly, approximately 50 percent of the sulphur content of coal will be held in this manner, normally in the form of the mineral, pyrite, or its immediate oxidation products. There is, however, another important consideration where the sulphur content of the coal is highly variable. Since coal was laid down under geological conditions where considerable uniformity is to be expected over large zones (indeed it is rare to find the coal substance varying greatly in ultimate chemical composition in a coal seam although coking properties may vary more widely in the same seam due to oxidation and other conditions that affect the reactive entities in the coal structure) the variations found are generally less than the wide swings in sulphur content reported in some commercially important coal seams. It is thought, therefore, that most of these swings in sulphur content are caused by the presence or absence of the mineral pyrite which, in some cases, may have been introduced naturally in an erratic manner during the period of the geological formation of the coal bed. Thus, a successful manner of removing pyrite from coal would not only lower the overall sulphur content of coal, but would also permit an important improvement in the reduction of variation of sulphur contents of coal produced from some seams.

The most important application of coking coals is to produce coke for use in the iron blast furnace process, in which a wide range of iron-bearing materials are smelted with coke. It appears probable that, when smelting iron ore of low grade, the sulphur and slag-causing constituents of coke are less important because these impurities can be more easily handled in the large slag volumes produced from low-grade ore. Conversely, however, when rich iron ore burdens are used (frequently well prepared in a uniform physical condition whether of sinter or of pellets), the lower impurity content results in low-slag volume in the furnace which, in turn, makes it difficult to handle cokes high in ash and sulphur contents without the expensive alternative of adding waste materials, such as gravel, to augment the quantity of slag produced. This latter practice, however, has been necessary in some blast furnace plants. Furthermore, the tendency towards the use of prepared iron ores has reduced the sulphur content of these ores to very low levels by virtue of the oxidizing conditions prevalent in the ore pretreatment processes. Sulphur-free natural gas may also be used as a fuel injectant in the blast furnace process. In effect, therefore, when these conditions prevail, the only substantial quantity of sulphur entering the furnace enters with the coke.

Taking these factors into account, it is believed that a 1 percent reduction in the ash content of coke provides a benefit of from 20 to 50 cents per ton of iron and that a 0.1 percent

reduction in the sulphur content provides a benefit of from 5 to 20 cents per ton of iron, over the range of practices now current in the North American steel industry.

With regard to the second problem, while considerable attention has been given, particularly in Great Britain, to the modification of conventional vertical slot coke ovens to permit higher temperature higher production operation (which would also allow the production of coke of lower sulphur content from coals of the same sulphur content) no practical realization of this development has thus far been achieved. Preheating of the coal remains the one important possibility for industrial development to obtain large increases in coke oven productivity (after exhausting the avenues presently being elaborated, notably the construction of high ovens to increase the batch size and use of refractories of improved thermal conductivity).

The very high-unit capital cost of coke is becoming an important economic problem in steel works. By preheating the coals to be coked in apparatus of reasonable capital cost and high efficiency, even when the preheating temperature of the coal is limited to the range of 250°–350° C., productivity advantages have been shown in both experimental and production scale ovens to amount to about 50 percent in favorable cases and about 40 percent in less favorable cases. There is little difficulty with the coking of preheated coals once the coals are charged into the coke ovens. The quality of coke produced remains usually unchanged or may even be improved when coals of weaker coking properties are used. The preheating technique has not yet been successfully realized on a production scale because of two major problems: (a) the lack of a satisfactory procedure for performing the heating, and (b) the lack of a procedure for preheating and charging wherein safety from explosions can be substantially assured.

The present invention seeks to provide a method of upgrading coking coals to lower ash and sulphur contents whereby the resulting coal is amenable to low cost, highly effective direct heating steps in the production of coke therefrom. More specifically, the invention contemplates the production of coal essentially free from fines as such but wherein the fines (from which explosions are normally initiated) are present as agglomerates with each individual particle therein coated with an oily material such as coke oven tar of characteristics chosen to decrease explosion hazards.

The invention will be described with reference to the accompanying drawing, the single figure of which is a flow sheet illustrating a preferred embodiment of the invention.

In accordance with the invention, coal fines are agglomerated into pellets of a size suitable for coke making. The coal fines, which will ordinarily be of about 14 mesh (Tyler Standard), may be those normally produced in mechanical mining operations or those particularly ground to a size fine enough to liberate the mineral matter from the coal (in extreme cases as fine as 60 percent −325 mesh), and, if desired, blended for the purpose. The pellets will ordinarily by of 1/16 to ¼ inch in size but may be of larger size if required. In conventional coke making a suitable pellet size range would be about 80 percent ⅛ inch.

Another important aspect of this invention is the preblending of coals of different ranks or types into the spherical agglomerates before charging to the coke oven. More intimate contact between the various coal constituents can be achieved in this way and this procedure can either reduce the proportion of the generally more expensive low-volatile coking coal required or can allow the use of a "marginal" coking coal otherwise difficult to incorporate into the oven coal blend without adversely affecting coke quality. It is also well known to the industry that the addition of tar has a beneficial effect when some coals are used, particularly those of low fluidity. This preblending technique can also be used to incorporate inert additives such as coke breeze, anthracite fines, petroleum coke, flue dust and other forms of iron oxide to improve either the strength of the coke or lower its cost depending upon the particular circumstances at a given plant. Iron oxide

additions have generally not been favored because of the possible danger of attack to the oven refractories (normally silica based). Incorporating the oxide inside the spherical agglomerates lessens the danger of contact of the oxide directly with the oven walls.

The spherical agglomeration procedure generally comprises the dispersion of the coal fines in an aqueous phase, addition of a liquid hydrocarbon as a bridging liquid, and controlled agitation to cause coating of each coal particle with oil and pelletizing of the coated particles. Since the coal substance is naturally hyperophobic, essentially any hydrocarbon liquid is suitable. But an important phase of the invention resides in the use of tars and other hydrocarbon byproducts of coking which are recovered on coking for recycling.

The oil-filled coal pellets are then separated as by screening from the water and any other mineral matter or the like not attracted to the oil phase. The agglomeration procedure is closely similar to that described in U.S. Pat. No. 3,268,071, Puddington et al.

The consistency of the aqueous dispersion, that is, the percentage of solids to water by weight, is about 10 to 40 percent. The hydrocarbon liquid is added in an amount of about 6 to 25 percent by weight of solids. Preferably, the aqueous dispersion is maintained at a temperature of above 100° F. when undiluted viscous tar is used as the hydrocarbon liquid, or, alternatively, a light solvent (which may also be a byproduct of the coking step) can be added to the tar to lower the viscosity in proportions sufficient (generally 10–15 percent by weight) to allow room temperature operation.

The mixing and agitation may be carried out in any suitable type of apparatus; for instance, a drum equipped with a bladed propeller type of mixer. Moreover, a specially developed apparatus in which a zone of high shear is produced in the annular space between a solid conically shaped vessel rapidly rotating inside another cone has been found to condition rapidly the tar-coal-water mixture and also to serve as a blockage-resisting pump. After formation, the pellets are separated from the water phase, as by screening or by use of such size separators as elutriators, cyclones, or spirals, and dried, preferably by an air-drying procedure.

During the agitation, conditioning or balling steps, it has been found desirable in some cases to add reagents to further the separation of the pyrite and mineral matter from the coal. In general, operating at a basicity (pH) of from 8 to 10 has enhanced separation and this can be achieved by lime additions. The use of depressants, such as cyanide ion, also aids in separation of pyrite. The presence of sodium silicate (which reagent can only be added after the preliminary balling step is well underway as it inhibits ball formation—at least with the Cape Breton coal studied), aids in the final agglomerate separation step when the elutriation process is used. The presence of bentonite is to be avoided as it also inhibits ball formation in the case of the coals studied.

In industrial application of the process, the hot water needed when undiluted coke oven tars are used as the bridging liquid, can be conveniently supplied from cooling water discharge of furnaces. Alternatively, surplus low-value steam can be condensed inside the balling tanks to supply both the makeup water and the heat requirement.

A direct relation has been found between the size of the agglomerates produced and the ratio of tar-to-coal used, and also with the time of agitation—in both cases increasing; with the first variable the most important.

An important advantage of the present process is not only to prepare the upgraded coal into a size range amenable for treatment in efficient preheating systems but also to produce the coal in a dewatered form. It is well known that the addition of a hydrocarbon liquid to a wet coal displaces the water from the coal surface. This step occurs during the spherical agglomeration process and the small pellets produced will generally contain less than 5 percent water and frequently as low as 3 percent provided steps are taken to avoid mechanical entrapment of water on the pellets. This may be accomplished in vibrating screens and other shaking devices known to the industry but the application of a crude vacuum at this stage has been found especially helpful. In contrast, filter cakes of coal produced after the application of other separation processes that do not include the stage of agglomeration but using the same feed coal size range, may contain as much as 20 percent water by weight. The economic advantage lies not only in the reduction of thermal energy needed to remove the water but thermal drying processes are potentially harmful to the quality of the coke produced due to the danger of oxidation to fine coal. In the event that preheating practices cannot be used for other reasons, a significant improvement in coke oven productivity of the order of 20 percent may be expected on using the agglomerates directly as compared with the same coal at a typical oven charge water content of 6 percent.

The hydrocarbon oil employed should be of low-sulphur content. Moreover, it is quite desirable, for economic reasons, that the oil be at least partially subject to reclaim for reuse in the agglomeration procedure and that any unreclaimed oil be otherwise usable. More specifically, it has been found that coke oven tars and the like can be used under appropriate conditions to effect separation in the agglomeration procedure set forth. It has been further found that at least one-half of this added oil or tar can be recovered in the normal coking process byproduct recovery system. The remainder of the tar not so recovered appears as additional fixed carbon of coke and additional oil byproducts.

Coal is difficult to preheat because of the fines contained, its water content, and its low-thermal conductivity. Moreover, the presence of fine coal on heating leads to explosion hazards. The spherical agglomeration process improves the porosity of coal beds to allow the internal passage of heating gases. The danger of explosion is minimized since the individual coal particles are bound into the agglomerates. It is inherent in the process that each particle of coal is coated with a layer of hydrocarbon. When the hydrocarbon is coke oven tar (in effect an already distilled liquid at a higher temperature than the preheating process) which is placed on the surface of the coal particles, the latter will only give up a minimum quantity of hydrocarbon to the preheating gas. Moreover, the tar hardens on preheating, strengthening the agglomerates to allow their transport without undue breakdown and also they become resistant to oxidation. This adds protection to the hot coal awaiting oven charging not available in other processes.

Several types of preheating equipment can be used including moving beds, travelling grate machines, or fluid or spouting beds as circumstances warrant. Waste gases from various processes at a steel plant can be made use of in two different ways. In the first way, a gas of low-calorific value and low utility. Such as blast furnace gas (approx. 90 B.t.u. per cu. ft.) can be precombusted and the resulting hot gaseous products passed through the preheating equipment. In the second way, gases already containing adequate sensible heat recovered from heating units, such as the firing chambers of coke ovens or blast furnace stoves, can be passed directly through the preheater. For the case where a combustible gas contains sufficient sensible heat to perform the coal preheating, then the hydrocarbon loss from the spherical agglomerates (at 300° C. about 3 percent by weight) enriches this gas for use elsewhere, if attractive. Generally, a contact time of from 10 to 15 minutes is adequate for the preheating step, and the temperature range used is 250° to 350° C.

A special case for carrying out the preheating step involves the use of an autogenous heating device. The quantity of hydrocarbons released on heating the agglomerates to 300° C. (about 3 percent by weight) if oxidized in situ in the preheating device is sufficient to provide the necessary thermal requirement. A preferred type of preheater (because of its inherently high capacity) has a hot zone at a temperature sufficiently high to oxidize the evolved gases immediately on their release and a time of passage of the spherical agglomerates such that their temperature does not exceed the desired level on traversing this high-temperature zone.

After preheating, the spherical agglomerates can be transported to, and charged into, the coke ovens in conventional equipment. Pneumatic methods of transport could also be used using a neutral carrier gas such as steam at the temperature of the agglomerates. Alternatively, advantage can be taken of their substantially spherical shape to allow chute-charging techniques. When the entire oven charge is made up of preheated coal, a gain in output of 40 to 50 percent as compared to standard wet coal charges will result.

Before the agglomeration stage, the coal fines suspension in the water and oil may be upgraded by an optional air flotation step. This step involves passing air bubbles upwardly through the suspension whereby small amounts of oil bridge the fines into larger particles of a size suitable for attachment to the rising air bubbles. After the aeration step, the amount of hydrocarbon liquid may be adjusted, if necessary, and the concentrate subjected to controlled agitation to effect agglomeration. Again, reagents such as lime to control basicity and well-known pyrite depressants may be used to aid mineral matter separation.

The process can be combined integrally with other separating techniques (such as the water cyclone) to allow preliminary separation of a portion of the pyrite. Alternatively, the process can be fed with the intermediate products of other established separating techniques, such as from jig or flotation circuits with or without preliminary size reduction.

The flow sheet indicates diagrammatically a typical succession of method steps in accordance with the invention. The method illustrated includes an initial separation step followed by a flotation step. The upgraded coal fines in aqueous suspension then pass into an agitator to which is fed a tar binder recovered from the subsequent preheating a carbonization steps. After the pelletizing step in the agitator, the contents are screened to remove the pellets from the remaining aqueous liquid.

A series of tests have been carried out in order to illustrate the effectiveness of the present invention. For the tests, there were selected a high-sulphur coal which was obtained from No. 26 colliery, Harbour Seam, Cape Breton County, Nova Scotia, and a low-volatile reference coal obtained from Pocahontas No. 3 seam, Wyoming County, West Virginia.

A typical analyses of these coals are,

TABLE I

Classification:	No. 26	Ref. lv coal
Rank (ASTM)	hv "A" b	lvb
Specific volatile index (unit basis)	169	209
Volatile matter (dmmfb), percent	35.5	18.7
Carbon (dmmfb), percent	87.7	91.3
Proximate analysis (db), percent:		
Ash	6.3	5.8
Volatile matter	36.9	18.2
Fixed carbon	56.8	76.0
Gross calorific value (dmmfb), B.t.u./lb	15,350	15,690
Ultimate analysis (db), percent:		
Carbon	83.6	85.0
Hydrogen	5.3	4.5
Sulphur	1.5	0.74
Nitrogen	1.7	1.2
Ash	3.9	6.1
Oxygen (by diff.)	4.5	2.4
Ash analysis, percent:		
SiO_2	33.4	49.4
Al_2O_3	20.6	32.3
Fe_2O_3	29.3	10.6
TiO_2	1.2	1.5
P_2O_5	0.6	0.2
MnO	0.03	
CaO	5.0	2.8
MgO	0.3	0.5
SO_3	4.6	2.4
K_2O	0.9	
Na_2O	1.8	0.4
Cr_2O	1.3	
As_2O_3	0.2	
ZrO_2	0.6	
BaO	0.1	

Agglomerates were initially prepared from the No. 26 coal fines with particles not substantially greater than ⅛ inch and at least 80 percent of which were −14 mesh (Tyler). The coal fines were dispersed in hot water of about 70° C. in the proportion of about 20 percent. The bridging liquid comprising a light coke oven tar was added to the dispersion in an amount of about 10 percent by weight of the coal.

The mixture was subjected to agitation in a 25-gallon drum stirred with a 9 inch diameter 3-bladed propeller, for about 60 minutes. After formation of the pellets they were separated from the water on a screen and air dried. The pellets used in the tests ranged in size from 1/16 to 3/16 inch. The tar content ranged from 9.8 to 12.5 percent, and the water content from 0.84 to 5.00 percent, the minimum consistent with satisfactory balling being preferred for economic reasons.

Typical charges were prepared for carbonization using the spherical agglomerated No. 26 coal fines, No. 26 coal crushed to about minus ⅛ inch, and the low-volatile (1v) reference coal also crushed to about minus ⅛ inch.

The charges were carbonized in two types of apparatus (1) the United States Bureau of Mines—American Gas Association (BM/AGA) 18-inch diameter retort and (2) the 12-inch Movable-Wall (MW) coke oven of the Mines Branch, Department of Energy, Mines and Resources of Canada. The latter oven is 12 inches in width and has a 500 lb. (nominal) capacity. The walls comprise silicon carbide tile with a high thermal conductivity in relation to silica brick and to simulate the conditions of heating in a commercial oven the heat input is programmed. The coal is charged at a flue temperature of 1,650° F. The temperature is then increased at a rate of 50° F./hr. to 1,950° F. and maintained at this temperature. The coke is pushed ½ hour after the center of coke has reached 1,850° F.

No attempt was made in these early tests to achieve mineral matter and pyrite rejection. The main objective was to prove the coking ability of the agglomerates and the degree of coke oven tar recycling that is possible.

The results of the tests are given in tables II, III, IV and V.

TABLE II.—CARBONIZATION IN BM/AGA APPARATUS

Test numbers	13-0 13-1	15-0 15-1 15-2	16-0 16-1	17-0 17-1 17-2
Identification:				
Coal blend, percent:				
Ref. lv coal	25	25.0		
No. 26 coal	75	37.5	100	50
No. 26 coal (spher. aggl.)		37.5		50
Carbonization test data:				
Weight of charge (wet), lb		¹160		
Bulk density in over (wet), lb./ft.³		¹46.8		
Free space in retort, in		3.0		
Coking temperature (average), °F		1,750		
Coking time, hr		8		
Coal analysis (as carbonized), percent:				
Moisture	1.8	2.9	1.4	1.0
Proximate analysis (dry):				
Ash	6.2	6.0	6.3	4.8
Volatile matter	32.2	31.0	36.9	35.1
Fixed carbon	61.6	60.1	56.8	60.1
Sulphur	1.10	1.10	1.00	1.34
Coal size, ⅛ x 0 in	80	80	80	80
Tar content of spher. aggl. percent	0.0	10-14	0.0	10-14
Sieve analysis of coke (cumulative percent retained on):				
4 in. sieve	0.0	0.0	0.0	0.0
3 in. sieve	3.2	1.8	5.9	4.1
2 in. sieve	47.1	37.3	45.3	28.1
1½ in. sieve	80.1	76.0	77.7	76.6
1 in. sieve	94.6	94.8	92.5	93.8
¾ in. sieve	96.7	96.6	95.4	96.0
½ in. sieve	97.3	97.1	96.5	96.6
Coke size: Mean size, in	2.00	1.90	2.00	1.91
Tumbler test for coke (ASTM) (cumulative percent retained on):				
Stability factor, 1 in. sieve	45.7	48.4	36.1	41.5
Hardness factor, ¼ in. sieve	67.1	66.8	62.9	60.6
Apparent specific gravity, proximate analysis of coke (dry), percent:				
Ash	7.0	6.7	8.3	6.5
Volatile matter	1.6	1.4	2.3	1.1
Fixed carbon	91.4	91.9	89.4	92.4
Sulphur in coke (dry)—coke produced, yield, percent:				
Coke: charge dry basis	71.1	70.4	69.9	69.4
Coke: coal dry basis	71.1	73.0	69.9	74.1

¹ Approximately.

TABLE III.—CARBONIZATION YIELDS (DRY BASIS) AND COKE QUALITY (BM/AGA APPARATUS)

Description of charge	25% lv coal 75% No. 26	25% lv coal 37½% No. 26 37½% No. 26 agg.	100% No. 26	50% No. 26 50% No. 26 agg.
Tar for agglomerates, pound	0.0	5.9	0.0	9.5
Yields:				
Coke, percent:				
Coke: charge	71.1	70.4	69.9	69.8
Coke: coal	71.1	73.0	69.9	74.0
Material balance, pound		+3.0		+6.4
Tar, gallon/ton:				
Coke: charge	11.1	13.8	11.7	14.6
Coke: coal	11.1	14.4	11.7	
Material balance, pound		+3.5		+3.1
Gas, cubic feet ton:				
Coke: charge	10,470	10,200	11,260	10,900
Coke: coal	10,470	10,477	11,260	11,400
Material balance, pound				+
Light oil, gallon/ton:				
Coke: charge	3.5	2.4	2.2	2.4
Coke: coal	3.5	2.6	2.2	2.6
Material balance, pound		−0.6	2.2	+0.2
Total material balance, pound	0.0	5.9	0.0	+9.7

TABLE IV.—GAS ANALYSIS OF BM/AGA TESTS

Test No	13	13-1	14	14-1	14-2	16	16-1	17	17-1
Coal blend, percent:									
LV ref. coal	25		25.0						
No. 26 coal	75		37.5			100		50	
No. 26 agg. coal			37.5					50	
(Percent by volume—air free:)									
Carbon dioxide	0.55	0.88	1.35	0.56	0.14	0.89	0.43	0.37	0.07
Unsaturated hydrocarbons (illuminants)	3.58	4.63	1.49	3.59	2.42	4.44	3.30	4.46	4.10
Hydrogen	60.97	57.66	63.65	59.93	65.52	54.65	57.71	56.91	59.33
Carbon monoxide	5.10	4.97	5.25	5.51	4.63	6.09	6.17	6.07	5.57
Paraffinic hydrocarbons	28.04	27.16	24.77	27.66	22.50	29.23	25.96	28.63	26.73
Nitrogen (difference)	1.76	4.70	3.49	2.75	4.70	4.70	6.43	3.66	4.20

TABLE V.—CARBONIZATION IN MINES BRANCH MW COKE-OVEN

Test No	334	340	367
Identification:			
Coal blend, percent:			
Ref. lv coal	25.0		
No. 26 coal	37.5	50	100
No. 26 coal (spher. aggl.)	37.5	50	
Ref. hv coal			
Carbonization test data:			
Weight of charge (wet), lb	497.9	498.1	506.1
Weight of charge (dry), lb	485.0	486.2	494.0
Coal size, percent ⅛ x 0 in	80	80	80
Moisture, percent	2.4	2.4	2.4
Bulk density in oven (wet), lb./ft.³	50.4	50.6	51.5
Bulk density in oven (dry), lb./ft.³	48.5	48.4	50.3
Coking temperature (average), °F	1,854	1,859	1,865
Coking time, hr/min	10-0	10-20	10-30
Coal analyses (as carbonized) percent:			
Proximate analysis (db):			
Ash	6.0	4.8	6.4
Vol. matter	31.0	35.1	34.0
Fixed carbon	63.0	60.1	59.6
Sulphur	1.10	1.34	1.68
Tar content of spher. agglomerates	10.5	10.5	(¹)
Sieve analysis of coke (cumulative percent retained on):			
4 in. sieve	2.3	4.5	5.5
3 in. sieve	17.4	31.4	37.2
2 in. sieve	72.4	80.2	82.9
1½ in. sieve	90.2	91.6	92.3
1 in. sieve	96.2	96.2	96.1
¾ in. sieve	97.5	97.1	97.0
½ in. sieve	98.0	97.7	97.5
Coke Size: mean size, in	2.41	2.64	2.73
Tumbler test for coke (ASTM) (cumulative percent retained on):			
Stability factor, 1 in. sieve	51.6	40.7	38.7
Hardness factor, ¼ in sieve	70.2	63.1	64.3
Apparent specific gravity	0.886	0.891	0.865
Coal expansion, p.s.i.:			
Maximum	0.9	0.6	0.4
Final	0.6	0.6	0.4
Coke Produced:			
Weight (dry), lb	347.9	338.5	348.6
Yield, percent:			
Coke: charge dry basis	71.7	69.8	70.5
Coke: coal dry basis	74.7	72.5	70.5
Coke analysis, percent:			
Proximate analysis:			
Ash	8.0		
Volatile matter	0.8		
Fixed carbon	91.2		
Sulphur	0.97		

¹ Nil.

The following is a comparison of the coke strengths based upon the Stability Factor, ASTM Tumbler Test for Coke:

TABLE VI

	Stability Factor	
	BM/AGA	MW
25% Ref. lv, 75% No. 26	45.8	51*
25% Ref. lv, 75% No. 26 (½ spher. aggl.)	48.4	51.6
100% No. 26	36.0	
100% (½ spher. aggl.)	41.5	40.7

*Estimated value based on experience with similar coals.

There was no observed significant difference in the Hardness Factor. In general, the coke size was somewhat smaller with the use of agglomerates. The quality of the coke produced from the BM/AGA apparatus compared favorably with that from the MW coke oven.

In general, there was no significant increase in the gas and light oil yields; the composition of the gas also remained essentially the same. The tar used for agglomeration appeared to be recovered in the form of carbon in the coke and increased tar yields (about 35–60 percent in coke and 65–40 percent in the tar). It is postulated that this ratio would vary depending upon the conditions of carbonization and the extent of gas cracking.

While the thermal treatment of the BM/AGA tests indicates that a 40–65 percent makeup of tar may be required in an integrated process, a tar balance using 100 percent agglomerates containing 10 percent added tar appears feasible. As conventional coke oven practice would be carried out usually at a higher temperature, the tar recovery in the form of tar would be somewhat less than indicated above, while the yield of coke would be higher.

The following conclusions may be drawn from the tests:

1. Use of spherical agglomerates in coal charges for coke production resulted in coke with better strength properties (high-Stability Factor) and with a slightly lower mean

size, both in the case of a typical coke oven char and an hv coal charge.

2. Tar used for agglomeration is recoverable in the form of fixed carbon in the coke (35–60 percent and in the tar recovery system (65–40 percent).

3. Gas yield and gas quality remain the same.

4. No change in light oil yield occurs.

5. From other results not reported here, the quality of the tar produced as measured by tests common in the industry was essentially unchanged.

In another example of this invention, run-of-oven feed sized coal normally 80 percent less than ⅛ inch in size was agglomerated after normal coal blending but without size reduction. In this case, after addition of the hydrocarbon bridging agent and agitating as before, only the fine fraction of the coal in the charge—that less than 10 mesh in size—formed spherical agglomerates. All the coal was coated with the hydrocarbon whether agglomerated or not. The rejection of mineral matter and pyrite was restricted at best to that free from the coal matter at the particular size distribution used. The mixture of agglomerates and large coal pieces was separated from the water slurry as before and being particulate with hydrocarbon coating was amenable to the preheating techniques already described. This alternate procedure is used when the rejection of pyrite and mineral matter is secondary to the benefit arising from preheating and has the advantage over the previous procedure in that less hydrocarbon is needed to convert the coal into a form suitable for preheating, i.e., 3 to 10 percent of the weight of the coal, depending upon the size range.

Another example of this invention is to produce a desirable feed for so-called form coke processes. In this latter type of coking process the coal is preformed frequently by briquetting or extrusion methods and then coked. The spherical agglomeration process produces an intimately blended feed containing tar of low mineral and pyrite content. In some cases the spherical agglomerates can be fed directly to a briquetting press. Where hot briquetting techniques are preferred, the spherical agglomeration product and procedure once again lends itself to preheating procedures but to the higher temperatures required (350°–700° C.) for the hot briquetting technique. Again, an important disadvantage of hot briquetting processes in the past was that hard to control fluid bed preheating steps were used with the possibility of oxidation of the coking coal. The briquettes whether produced hot or cold can then be fed to the vertical shaft carbonization process.

We claim:

1. Process for producing coke which comprises dispersing a body of coal fines in water to form an aqueous dispersion of said coal fines, adding a bridging liquid consisting essentially of a coke oven tar to said dispersion, said water in said dispersion being sufficiently hot to render said coke oven tar liquid, displacing the water on the individual fines of said body with said coke oven tar by agitating the resulting mixture of said dispersion and bridging liquid thereby to coat each said individual fine of said body with said coke oven tar, forming sub-

stantially spherical agglomerates of said coated fines by continuing said agitation of said mixture while avoiding mechanical entrapment of water in said agglomerates, separating said agglomerates from the water in said mixture, drying said agglomerates, preheating said dried agglomerates in a preheating device to a temperature within the range of a about 250° to about 350° C. by burning in situ combustible gases including those arising on heating said agglomerates to said temperature range, transporting the preheated agglomerates from said preheating device and charging said preheated agglomerates into a separate coke oven, and carbonizing said agglomerates in said coke oven to form coke.

2. Process for producing coke as defined in claim 1, wherein said bridging liquid is added in an amount of 6 to 20 percent based upon the weight of said coal fines.

3. Process for producing coke as defined in claim 1, wherein said dispersion contains about 10 to 40 percent by weight of said coal fines.

4. Process for producing coke as defined in claim 1, including the step prior to said agitation step, of aerating said mixture to form rising air bubbles therein and cause bridging of said fines into larger particles suitable for attachment to said bubbles and removing sediment.

5. Process for producing coke as defined in claim 1, including the step of forming a blend of said dried agglomerates and particles of natural coal and then carbonizing said blend.

6. Process for producing coke as defined in claim 1, including the steps of controlling the basicity of said mixture in the pH range of 8–10 and adding a pyrite depressant to said mixture to aid in separation therefrom of pyrite and other mineral matter.

7. Process for producing coke as defined in claim 1, wherein the said preheating step is performed by direct contact of combustible gases containing sufficient sensible heat, and wherein the hydrocarbon loss from said agglomerates during said preheating step is transferred to said gases for enrichment thereof and subsequent recycling.

8. Process for producing coke as defined in claim 1, including the step of adding to said coal fines iron oxide-containing materials.

9. Process for producing coke which comprises agglomerating coal fines by preparing an aqueous dispersion thereof, adding a bridging liquid consisting essentially of a coke oven tar to said dispersion, said water in said dispersion being sufficiently hot to render said coke oven tar liquid, and agitating the resulting mixture to cause substantial displacement of the water on said particles by said bridging liquid and to form substantially spherical agglomerates of said fines containing said coke oven tar, separating said agglomerates from the aqueous phase of said mixture, drying said agglomerates, preheating said agglomerates to a temperature within the range of 350° to 700° C. by burning in situ combustible gases including those arising on heating said agglomerates to said temperature range, briquetting said preheated agglomerates and carbonizing said briquetted agglomerates to produce form coke.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. _____3,637,464_____ Dated_January 25, 1972___

Inventor(s)_John H. Walsh, Basil J.P. Whalley, John E. Botham_
          and Syed M. Ahmed
     It is certified that error appears in the above-identified patent
and that said Letters Patent are hereby corrected as shown below:

In the heading on the first page of the patent under [72],

the name of the fourth invention should be added as

follows:

     --Syed M. Ahmed, Ottawa, Ontario--

     Signes and sealed this 15th day of August 1972.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.   ROBERT GOTTSCHALK
Attesting Officer   Commissioner of Patents