

July 6, 1965

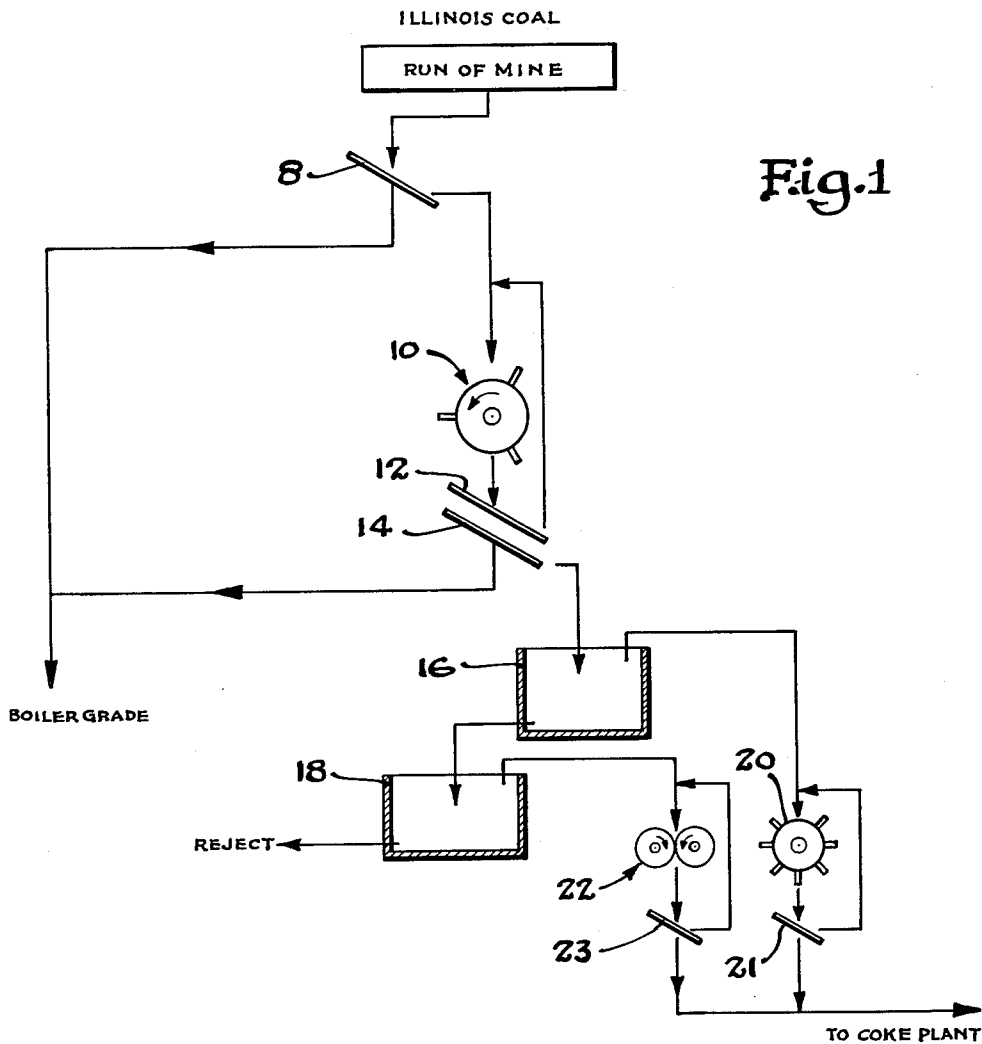
M. O. HOLOWATY

3,193,471

COKING PROCESS

Filed Oct. 24, 1961

2 Sheets-Sheet 1



Inventor
Michael O. Holowaty
By Davis, Lindsey, Hibben & Noyes
Attorneys

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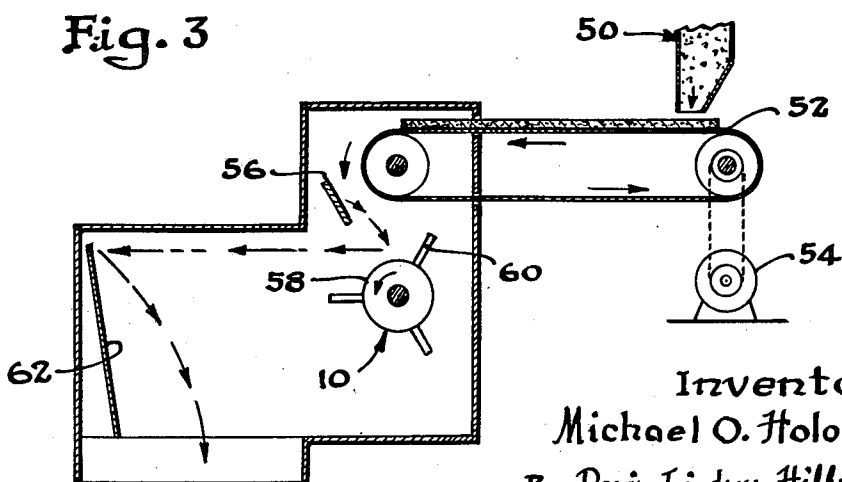
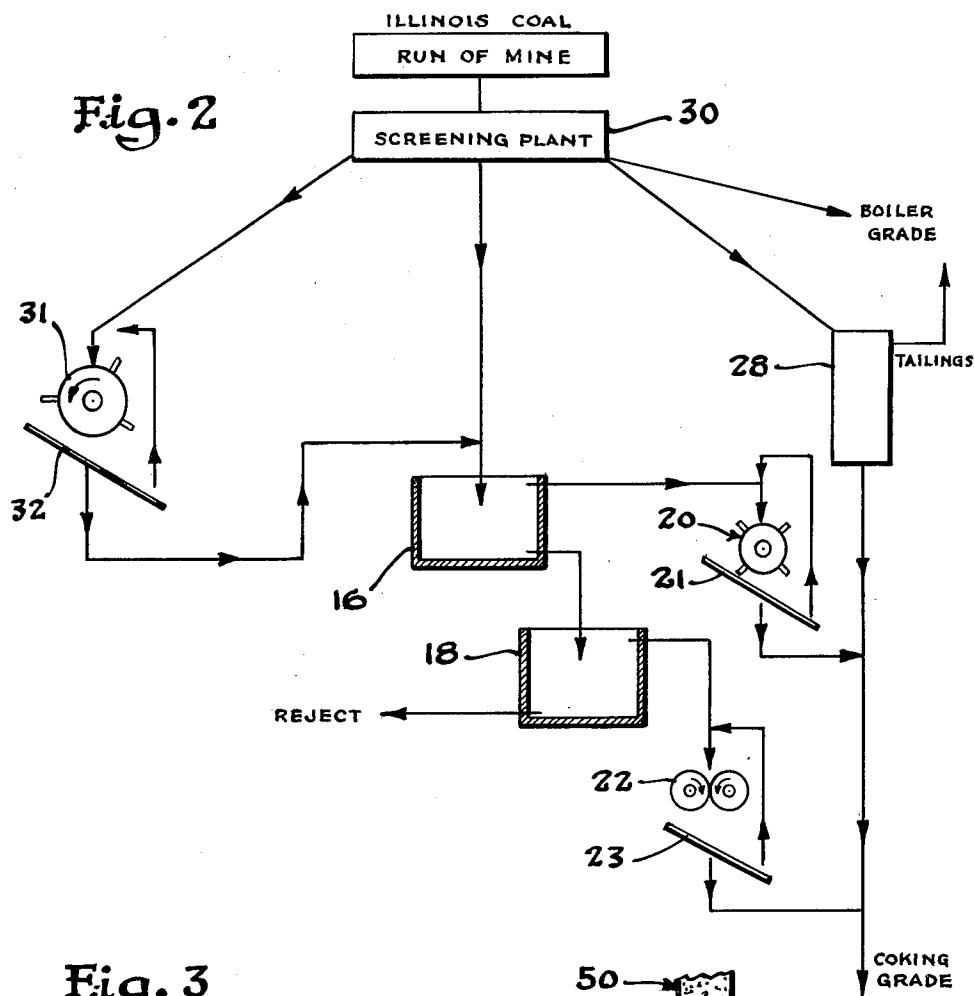
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COKING PROCESS

Michael O. Holowaty, Gary, Ind., assignor to Inland Steel Company, Chicago, Ill., a corporation of Delaware
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7 Claims. (Cl. 202—25)

The present invention relates broadly to the preparation of metallurgical coke from a marginal coking coal, and more particularly to a process and means for the preparation of metallurgical coke from an Illinois-type coal.

The Illinois coal basin is the second most important coal field in the United States and is likely to become more important in the future, since the state of Illinois leads in the minable bituminous coal reserves in the Western Hemisphere. The Illinois coals produced by this area, as exemplified by Illinois No. 6 coal, have a "banded" or layer structure which is very pronounced and in which each layer consists of a distinct carbon-bearing material not only having a different appearance but also having different chemical and coking properties. According to one system of petrographic nomenclature, Illinois coal No. 6, for example, is composed essentially of a mixture of four coal ingredients namely: vitrain, clarain, fusain, and durain, with each of the said ingredients comprising one of the visually identifiable layers or areas of the coal.

The vitrain and clarain components of a coal have good coking properties, but these coking properties can be readily destroyed by weathering or natural oxidation on prolonged exposure to air which renders the particles incapable of coalescing to form a viscous mass and a coherent cellular coke when heated to carbonizing temperatures. The fusain and durain components of the coal are relatively inert and have relatively poor coke-forming ability. The combination of these components in the Illinois coals renders the Illinois coals relatively poor in coking properties, and heretofore Illinois coals have not been competitive with coals from eastern coal fields in the preparation of metallurgical coke.

It has previously been suggested that an improved coke can be produced by preparing mixtures of different natural coals some of which have good coking properties and other of which have poor coking properties. These previously suggested coking processes have further contemplated having certain of the coals in a relatively small particle size and other coals being in a relatively much larger particle size without, however, limiting specifically the manner of subdividing the coals or the manner of separating the several ingredients within a single coal during the process of subdividing the coals. These prior art methods of coking have therefore not been successful when applied to Illinois coals and it has been necessary heretofore to use coals other than Illinois coal for the production of satisfactory metallurgical coke.

It is therefore a primary object of the present invention to provide a process and means of producing a satisfactory metallurgical coke from a bituminous coal preparation which normally is incapable of producing metallurgical coke.

It is a further specific object of the present invention to provide a process and means of producing a satisfactory metallurgical coke from a coking mixture containing substantial amounts of an Illinois coal which is normally incapable of producing acceptable metallurgical coke.

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Other objects of the present invention will be apparent to those skilled in the art from the detailed description and claims to follow when read in conjunction with the accompanying drawing wherein:

FIGURE 1 is a flow sheet diagram of a coking process illustrating one embodiment of the present invention;

FIGURE 2 is a flow sheet diagram illustrating a modified form of the present invention; and

FIGURE 3 is a schematic side elevational view of a controlled abrasion-free impingement crushing apparatus employed in practicing the present invention.

It has been discovered that the foregoing objects of the present invention can be achieved by effecting a controlled particle size reduction and controlled separation of an Illinois-type coal into at least two petrographic fractions and thereafter combining the fractions having distinct and carefully controlled particle sizes to form a coking blend which contains from about 50 percent to 100 percent Illinois coal. Accordingly, an Illinois coal, such as Illinois No. 6 coal, is separated into one fraction containing the fragile but good coking vitrain and clarain components in a moderately finely subdivided form and into another fraction containing primarily the non-coking inert components thereof, such as durain and fusain, in a relatively more finely divided form. Thereafter the two fractions are recombined into a coking blend which can be coked to form good metallurgical coke thus making the previously marginal coking coals of Illinois competitive with the eastern coals for the production of metallurgical coke.

In the preparation of a metallurgical coke blend from Illinois coal, it is important to grind or otherwise subdivide the durain component thereof very finely but at the same time avoiding overgrinding the vitrain and clarain components. Furthermore, it is most important to effect as complete a separation of the coking and non-coking components as possible so that the inert components are removed or finely subdivided in the coking mixture. If the Illinois coal or similar coal is subjected to any of the usual or previously suggested methods of preparation for coking, however, the important vitrain and clarain coking constituents are ground too finely which results in the loss of the binding power thereof. Also, the inert non-coking constituents, such as durain, shale, or slate, are not sufficiently segregated from the coking constituents and are not ground sufficiently finely to avoid centers of weakness in the coke.

In order to make it possible to utilize Illinois coal for the production of metallurgical coke, it has been found necessary to effect separation of the Illinois coal into its petrographic constituents by crushing or other disintegration means which avoids abrading the coal. Particularly good results are achieved by employing a substantially abrasion-free impingement finger crusher and process illustrated in FIG. 3 of the drawing. When the layered Illinois coal is subjected to the herein disclosed impingement crushing process, the lumps of the coal tend to fracture along the planes separating the individual petrographic layers. The oversize material is recycled to the crusher so that eventually all of the coal passes through the primary or "scalping" screen. The resulting mixture is comprised of the partially separated petrographic constituents of the coal having a predetermined maximum particle size. At this point the very small particles formed

can be separated by means of a second screen and may be used as boiler fuel or introduced directly into the final coking mixture.

In order to transform the resulting fragmented and screened mixture into a satisfactory coking mixture, it has unexpectedly been found necessary to subject the screened mixture to a two-stage liquid density separation treatment using aqueous calcium chloride, zinc chloride, or the like as the liquid separating medium. In the first stage density separation treatment the liquid preferably has a specific gravity of between about 1.20 and about 1.30, and in the second stage separation treatment the liquid preferably has a specific gravity of between about 1.35 and about 1.45. By using a liquid density separation procedure on the impingement-crushed coal to effect a separation into major petrographic fractions, as opposed to a screening or other granulametric separation procedure, it has been found that the good coking coal components are concentrated more effectively with the vitrain and clarain being concentrated in the relatively low density, low ash fraction comprising the "float" portion of the first stage density separation procedure, and the usable portion of the inert durain component being concentrated and recovered in the "float" portion of the second stage separation procedure. The instant two-stage liquid density separation procedure, while effecting a petrographic separation, simultaneously enables a large proportion of the minerals to be discarded along with the sulphur and other inert constituents and thereby very substantially reduces the ash content of the coke, since the ash constituents are largely concentrated in the "sink" portion of the second stage density separation procedure.

The separated fractions of the coal are then each subjected to separate and selected particle size reduction by crushing or grinding. The grinding of the low ash vitrain and clarain fraction is carefully controlled to avoid overgrinding and the fraction is maintained within a particle size range below six mesh, U.S. standard screen size, with a minimum amount of the particles being below about 20 mesh. The usable durain component is ground more finely to reduce the particle size thereof as much as possible until all of the material of the latter fraction passes through a 20 mesh U.S. standard screen. The liquid density separation and grinding or crushing procedure in every instance effects a concentration of the good coking constituents in the coarser fraction and provides gradually smaller particle sizes for the fractions having increasingly higher percentages of inert constituents.

In order to further illustrate the present invention without, however, limiting the scope thereof to the particular ingredients or proportions shown, the following specific embodiments are given:

EXAMPLE I

As shown in FIG. 1, run-of-the-mine Illinois No. 6 coal, screened on screen 8 to remove coal particles less than $\frac{3}{8}$ inch, is crushed in the abrasion-free finger impingement crusher 10 shown in FIG. 3 of the attached drawing rotated at a rate of 1000 r.p.m. The crushed material is screened on screen 12 to insure that all of the material has a particle size less than about 2 inches in diameter and the coal less than $\frac{3}{8}$ inch in diameter is removed by screen 14. The crushed material which has a particle size of less than $\frac{3}{8}$ inch is used for boiler feed or the like, if coking is not to be done immediately. The crushed material having a particle size of between about $\frac{3}{8}$ inch and 2 inches is subjected to a first-stage density separation in a liquid density separator 16 using a liquid such as zinc chloride having a specific gravity density adjusted to 1.25. The material which sinks (specific gravity above 1.25) is then subjected to a second density separation in a liquid having the specific gravity of 1.40.

The material which sinks in the second stage separator 18 is comprised mainly of high ash material containing sulphur and other minerals and is discarded. The chemi-

cal analysis of the "float" portions of the two density separation treatments, and the analysis of the run-of-mine Illinois No. 6 coal are shown in the following Table I:

Table I

CHEMICAL ANALYSIS OF BENEFICIATED ILLINOIS COAL

	Volatile matter	Fixed carbon	Ash	Sulfur
Run-of-mine.....	39.24	53.32	8.30	1.12
Specific gravity fraction:				
1.25 (-6M).....	40.85	55.55	3.60	0.77
1.40 (-20M).....	41.00	53.95	5.05	1.03

The float material of the first density or gravity separation (specific gravity 1.25 or less) provides material which is essentially a concentrate of vitrain or clarain and is crushed preferably by the herein disclosed impingement finger crusher 20 until passing through a screen 21 having a mesh size of 6, U.S. standard, with a minimum of very fine material being formed.

The float material of the second density separator (specific gravity between 1.25 and 1.40) consists of a mixture of the coking and non-coking constituents which must be ground considerably finer in order to unlock or liberate the good coking vitrain or clarain components and to finely divide the inert durain component to avoid large centers of weakness in the subsequently formed coke. Accordingly, the "float" material of the second stage separator is crushed by a roll crusher 22 until all of the material passes through a 20 mesh screen 23, U.S. standard. Thereafter, the two "float" materials from the first and second stage density separation treatments which have been separately subdivided are recombined to form a coke mixture or blend which is processed in the conventional manner to produce metallurgical coke.

In the following Table II is given the standard analysis of the coke blend produced in the above described manner (A-3), along with the analyses for:

(1) A coke blend (A-2) formed by crushing an identical Illinois No. 6 coal with the said finger impingement crusher of Example I, screening the product through a U.S. standard mesh screen and grinding the oversize material to minus 20 mesh without employing any density separation treatment;

(2) A coke blend (A-1-e) produced with an identical sample of Illinois No. 6 coal as in Example I (Test A-3) and processed by passing the coal through the standard hammer mill in use in the conventional coking plant, screening on a No. 6 mesh screen, and subsequently roll crushing the material larger than 6 mesh to a maximum of 20 mesh, also without employing density separation, and blending the resulting materials having a maximum size of 6 mesh and 20 mesh respectively to form the coking blend; and

(3) A coke blend (A-1) for a standard hammer mill grind plant coke blend:

Table II

BLEND PREPARATION AND COMPOSITION

Test No.	Blend analyses			
	Volatile matter	Fixed carbon	Ash	Sulfur
A-3.....	38.65	55.79	5.56	1.04
A-2.....	37.40	55.50	7.10	1.11
A-1-e.....	37.00	55.60	7.40	1.05
A-1.....	37.00	55.60	7.40	1.05

Following the coking of the foregoing coke blends of Table II in the conventional manner, the resulting coke products exhibit the chemical and physical properties shown in the following Table III:

Table III

CHEMICAL AND PHYSICAL PROPERTIES OF COKED BLENDS

Test No.	Chemical analyses (Percent)				Physical properties			
	VM ¹	FC ²	Ash	Sulfur	HTCSI, ³ p.s.i.	Stability, ⁴ percent	Hardness, ⁴ percent	Percent braize
A-3-----	1.10	90.50	8.40	0.80	4,000	40.0	64.9	3.74
A-2-----	1.05	90.05	8.90	0.82	3,600	36.6	63.1	4.01
A-1-e-----	1.00	87.00	11.20	0.77	(9)	37.4	58.6	6.97
A-1-----	1.40	88.60	10.00	0.79	3,275	29.9	69.7	3.02

¹ Volatile Matter.² Fixed Carbon.³ High Temperature Compression Strength Index; See: Blast Furnace and Steel Plant, vol. 48, p. 443, May 1980.⁴ Tumble test data.⁵ No sample; coke not suitable for testing.

From the data of Table III, it will be evident that the preparation of the coke blend according to the procedure of Example I (Test A-3) embodies all the essential conditions and procedures which are required to permit the effective use of an Illinois coal for the production of satisfactory metallurgical coke and, if the operating conditions and procedures are not employed in combination, the Illinois coal cannot be used for the production of the metallurgical coke.

It has also been found that the coke product from the coke blend produced in Example I (Test A-3) can be further improved by including in the coke blend a finely divided clarain-vitrain fraction such as that screened from the Illinois coal at the mine prior to shipment thereof. Since the finely divided clarain and vitrain coal particles would be oxidized and lose their coking properties if shipped any distance from the mine, they must be used only when coking is done at the mine or adjacent thereto. When the coking operation is performed at the mine, the finely divided vitrain and clarain fractions can be incorporated in the coke blend, in accordance with the following Example II:

EXAMPLE II

As shown in FIG. 2, run-of-mine Illinois coal No. 6 is screened at the mine screening plant 30 with the particles below 20 mesh, U.S. standard being discarded for boiler fuel or the like and the remainder being separated into a first fraction having a screen size between 6 mesh and 20 mesh, U.S. standard, a second fraction having a particle size less than 1 inch and greater than 6 mesh, U.S. standard, and a third fraction having a particle size greater than 1 inch.

The said third fraction obtained is then crushed in an impingement crusher 31, preferably of the spaced finger type shown in FIG. 3 of the drawing, wherein the particle size is reduced so that all the material passes through a 2-inch screen 32 with a minimum amount of fines being produced. The portion thereof having a particle size less than 20 mesh, U.S. standard, is preferably separated by screening and discarded (not shown). The portion thereof having a particle size between 2 inches and 20 mesh is combined with the said second mine screen fraction and is subjected to the identical two-stage liquid density separation treatments and particle size reduction treatment described in Example I. The two resulting products are combined and formed into a coke blend, along with the first fraction of the mill screening plant which has been cleaned, preferably on a Deister table 28 to remove the heavier inert portion thereof. The resulting blend which

comprises about 75% of the initial run-of-the-mine coal sample is carbonized in the usual manner with or without the addition of other coal or other additives to produce metallurgical coke.

EXAMPLE III

Run-of-the-mine Illinois No. 6 coal, as shipped by the mine, is subjected to the following treatment in accordance with the process of Example I: crushing in the abrasion-free finger impingement crusher of the present invention, the two-stage liquid density separation treatment, selective particle size reduction, and recombining to form a coking blend, precisely as in Example I. The thus treated Illinois No. 6 coal sample is combined with an equal quantity by weight of Bishop coal which has been crushed by conventional crusher rolls until it passes through a 6 mesh, U.S. standard screen. The resulting coke blend (A-6) is then coked in a conventional manner to produce metallurgical coke.

In the following Table IV is given the standard analysis of the coke blend produced in the above described manner (A-6) along with the analysis for:

(1) A second coke blend (A-5) prepared by blending 50 percent Illinois coal No. 6 with 50 percent Bishop coal ground by a conventional roll crusher to a -6 mesh, U.S. standard screen size and wherein the said Illinois No. 6 coal is crushed with the said abrasion-free finger impingement crusher of the present invention, screened with a 6 mesh screen and grinding the oversize material to -20 mesh screen size without employing another density separation treatment, and

(2) A coke blend (A-4) prepared of equal quantities of Illinois No. 6 and Bishop coal both subdivided by standard hammer mill grinding apparatus conventionally employed at a coke plant.

Table IV

BLEND PREPARATION AND COMPOSITION

Test No.	Composition		Blend analyses			
	Percent Ill. coal	Percent Bishop coal	VM	FC	Ash	Sulfur
A-6-----	50	50	29.50	64.50	6.00	0.78
A-5-----	50	50	30.00	63.70	6.30	0.84
A-4-----	50	50	29.35	64.10	5.55	0.76

The coke products produced from the foregoing coke blends of Table IV exhibited the chemical and physical properties shown in the following Table V:

Table V

CHEMICAL AND PHYSICAL PROPERTIES OF EXPERIMENTAL COKES

Test No.	Chemical analyses, percent				HTCSI (p.s.i.)	Stability, percent	Hardness	Percent braize
	VM	FC	Ash	S				
A-6-----	1.05	91.00	7.95	0.72	4,740	55.8	66.9	1.18
A-5-----	1.00	90.50	8.50	0.76	3,600	53.5	70.8	1.19
A-4-----	2.10	88.65	9.25	0.70	3,230	44.2	70.6	1.63

It will be evident from the foregoing table that the metallurgical coke product (Test A-6) prepared from Illinois coal processed according to the conditions set forth in Example III exhibits the best metallurgical coke properties. In addition to exhibiting high tumbler stability value, the coke of Test A-6 also has the highest high-temperature compression strength index (HTCSI). The structure of the coke product of Test A-6 closely approaches what is believed to be the ideal metallurgical coke structure.

The comparative data of Tables IV and V also show that the property of the coke product produced from the blend of Bishop coal and the Illinois coal depends primarily on the method of preparation of the Illinois coal, thereby showing the importance of using in combination the finger impingement crusher and density separation procedure of the present invention. Thus, for example, while the coke product of Test A-4 is characterized by relatively good hardness properties (70.6), it exhibits low stability and marginal high temperature compression strength index, 44.2% and 3230 p.s.i., respectively. The coke product of Test A-5 did not have materially improved hardness properties as compared with the coke of Test A-4 but did have increased tumbler stability (up 21% to 53.5%) and had a slightly elevated high-temperature index. The coke structure of Test A-5 is improved over the coke of Test A-4 but is still not uniform enough to completely eliminate stresses and strains caused by the larger particles of the inerts, as evidenced by the substantially lower HTCSI of coke "A-5" compared with coke "A-6."

The impingement crusher 10 with the associated apparatus shown in FIG. 3 of the drawing has been found particularly well adapted for effecting a selective reduction in the particle size of the Illinois coals and other layered coals having like properties without producing an excessive quantity of finely divided vitrain and clarain components. The run-of-the-mine Illinois coal is fed from the hopper 50 onto a flexible endless conveyor belt 52 driven by a suitable variable speed drive means 54 and associated elements. The coal is discharged from the belt 52 and allowed to fall freely onto a deflector plate 56 positioned below the end of the conveyor belt 52 and substantially reverses the direction of travel of the coal to deflect the coal into the path of the rotor member 58 of the impingement crusher apparatus. The large particles of coal are sharply struck by the spaced fingers of the rapidly rotating rotor member 58 and projected tangentially along a generally horizontal path against a corrugated steel plate 62 disposed at a slight angle with respect to the vertical. The larger coal particles are thus struck with essentially two impact blows, once by the fingers 60 of the rotor member 58 and again when the particles strike the corrugated steel impact plate 62. The smaller particles which can pass between the spaced fingers 60 are spared further substantial crushing.

The Illinois coal No. 6 used in the specific examples in addition to being characterized as having a pronounced "banded" or layer structure is further classified as a high-volatile B bituminous coal. Most of the Illinois coals fall within the high-volatile C classification (11,000-13,000 B.t.u./lb. and the high-volatile B classification 13,000-14,000 B.t.u./lb. Illinois coals also give a somewhat higher oxygen analysis (8%) than the high-volatile eastern coal (5.2%). In the following Table VI are given the average analyses of run-of-mine Illinois No. 6 coal:

Table VI

	Percent
Moisture -----	4-18
Volatile matter -----	31-40
Ash -----	7-14
Fixed carbon -----	42-56
Sulfur -----	0.7-2.5

In Table VII is given the fluidity values for Illinois No.

6 coal, and the fluidity of the eastern and western high-volatile coals:

Table VII

GIESELER PLASTOMETER DATA

	Maximum fluidity, dia. div./min.
Illinois coal No. 6 -----	80
Eastern coal -----	37,500
Western coal -----	10,500

It will be understood that the present invention is particularly concerned with the treatment of the marginal or non-coking Illinois coals, such as Illinois coal No. 6. Other Illinois coals, such as Illinois coal No. 5, can also be prepared into a satisfactory metallurgical coke blend in the same manner as described herein. It will be further appreciated by those skilled in the art that other "banded" bituminous coals having in excess of 12 percent volatile matter and comprised of distinct layers or isolated sections of carbon-bearing material, such as vitrain, clarain, fusain, and durain, can be processed in accordance with the present invention to provide metallurgical coke.

It will also be apparent from the foregoing disclosure that by processing Illinois coal in accordance with the present invention, it is possible to use between about 50 percent and 100 percent marginal coking Illinois coal in a coke blend which produces highly acceptable metallurgical coke.

Others may practice the invention in any of the numerous ways which are suggested to one skilled in the art, by this disclosure, and all such practice of invention are considered to be a part hereof which fall within the scope of the appended claims.

I claim:

1. In a process of preparing a metallurgical coke blend from a marginal coking coal the improvement which comprises; crushing a marginal coking coal containing in excess of 12% by weight volatile matter and having a plurality of distinct petrographic layers with at least one layer comprised of a coking coal component selected from the group consisting of vitrain and clarain, and at least one other layer comprised of a non-coking coal component selected from the group consisting of durain, fusain, slate, and shale to separate the said layers and produce a major proportion of fragments having a particle size between about 2 inches and about $\frac{3}{8}$ inch with a minimum amount of finely divided vitrain and clarain coal components, subjecting the fragmented coal containing said coking and said non-coking coal components in substantially their original proportion to a first liquid density separation treatment wherein the liquid has a specific gravity between about 1.20 and 1.30 to separate the said fragmented coal into a portion which floats and a portion which sinks therein, crushing the portion of said fragmented coal which floats in said first density separation treatment to a particle size which passes through the 6 mesh screen but larger than 20 mesh, subjecting the portion of said fragmented coal which sinks in said liquid density separation treatment to a second liquid density separation treatment wherein the liquid has a specific gravity of about 1.35 to 1.45, crushing the material which floats in said second liquid density separation treatment until all said material passes through a 20 mesh screen, and combining said crushed portions of said fragmented coal which float in the said first and second density separation treatments in a coking blend suitable for use in the production of metallurgical coke.

2. A process as in claim 1 wherein a part of said fragmented coal which has a particle size of less than 20 mesh is removed and discarded prior to said first liquid density separation treatment.

3. A process as in claim 1 wherein the liquid employed in said first liquid density separation treatment has a specific gravity of about 1.25 and the liquid in said second liquid density separation treatment has a specific gravity of about 1.40.

4. A process as in claim 1 wherein the said coal is an Illinois coal having distinct petrographic layers of vitrain, clarain, durain, and fusain.

5. A process as in claim 1 wherein said coal is Illinois No. 6 coal.

6. In a process of producing metallurgical coke from an Illinois type coal, the improvement which comprises; subjecting an Illinois type marginal coking coal having a plurality of distinct petrographic layers with at least one layer comprised of a coking coal component selected from the group consisting of vitrain, clarain, and at least one other layer comprised of a substantially non-coking coal component selected from the group consisting of durain, fusain, slate and shale to impingement crushing to separate the said layers and produce a major proportion fragments having a particle size between about 2 inches and about $\frac{3}{8}$ inch with a minimum amount of finely divided vitrain and clarain, separating the said fragmented coal to recover a major first fraction having a particle size greater than 20 mesh and less than 2 inches and leaving a minor second fraction having a particle size less than 20 mesh, subjecting said first fraction containing said coking and said non-coking coal components in substantially their original proportion to a first liquid density separation treatment wherein the liquid has a specific gravity of about 1.25 to separate said first fraction into a portion which floats and a portion which sinks, crushing said portion which floats to a particle size which

passes through a 6 mesh screen, subjecting the said portion which sinks to a second liquid density separation treatment wherein the liquid has a specific gravity of about 1.40 to recover a second float fraction, crushing said second float fraction until said material passes through a 20 mesh screen, and incorporating the first float portion which has been crushed to a particle size smaller than about 6 mesh and the said second float fraction which has been crushed to a particle size smaller than about 20 mesh in a coking blend to form a metallurgical coke on heating said blend to a carbonization temperature.

7. A process as in claim 6, wherein said marginal coking coal is Illinois No. 6 coal.

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MORRIS O. WOLK, *Primary Examiner.*

ALPHONSO D. SULLIVAN, *Examiner.*