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3,560,346

PROCESS OF PRODUCING SHAPED COKE

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ABSTRACT OF THE DISCLOSURE

Process of producing coke pellets bokies in a rotary kiln comprising feeding to the kiln carbonaceous matter having a high volatile content, an oxygen containing gas, and cokable pellets comprising a mixture of a substantially non-caking carbonaceous material and a highly coking carbonaceous material; coking the pellets in the rotary kiln; simultaneously burning the volatiles produced in said coking and the volatiles produced from the high volatiles carbonaceous matter to produce substantially all of the heat required to operate the process; and simultaneously producing from the high volatiles containing carbonaceous material the substantially non-caking carbonaceous material which is used in the pellet formation. On an overall basis there is added to the kiln highly caking coal, oxygen and high volatiles containing carbonaceous material.

The pellets are heat hardened in the kiln by raising their temperature at a rate of at least 15° C. per minute to a maximum temperature of about 500 to 1,000° C.

This application is a continuation-in-part of application Ser. Nos. 581,454, filed Sept. 23, 1966 and 664,597, filed Aug. 29, 1967, now abandoned.

For the past several years the employment of ore agglomerates of substantially uniform size and uniform shape, such as spherical sintered products and pellets, in blast furnace operations has been found to be desirable because such ore agglomerates permit a considerably higher throughput than when such furnace is loaded with ore agglomerates having components which are of varying sizes and shapes. In order to be able to profit to the maximum possible extent from the advantages obtainable through the use of uniformly sized and shaped ore agglomerates, it has been proposed that the additives used in combination with the ore be employed in a substantially uniform grain size and shape. To date, this has been accomplished exclusively by screening techniques.

A further proposal for maintaining the shape and size of the material charged into the blast furnace as uniform as possible is based on the incorporation of additives directly into the ore agglomerates. In this manner, the additives do not impair the uniformity of grain size and shape of the charged ore material.

In connection with this latter proposal the coke which is used should also be charged in a carefully regulated size range, e.g. in a grain size of about 9–12 mm. However, it has not yet proven possible, from a mechanical and/or technical point of view, to charge the coke in the same range of grain sizes as the ore agglomerate, particularly where substantially uniformly shaped ore pellets or briquettes are utilized.

Coke is generally produced in order to provide a fuel which has a reactive surface and an enriched carbon

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content and to utilize the volatile constituents thereof which are removed by the carbonization of the coal. Coke having special properties is particularly useful in metallurgical processes, such as the blast-furnace process or foundry processes. This coke must have a certain minimum crushing strength, abrasion resistance and reactivity. It is also required to have a predetermined, substantially uniform particle size. These requirements have in the past been fulfilled only if the coke was made by orthodox processes from specially selected grades of coal which contain about 20–30% of volatile constituents (related to air dried coal) and which have a swelling index higher than 4. These grades of coal amount only to about 10% of the known coal deposits.

Processes are known by which coke, particularly shaped coke, e.g. in the form of briquettes, is made from gas coal or from slightly caking or non-caking coal or mixtures of such grades of coal. In these processes, the coal, possibly subjected to a preliminary heat treatment and admixed with a binder if desired, and is briquetted and hardened and/or carbonized by the action of heat (German Pat. No. 881,188, printed German application No. 1,180,713, German Pat. No. 834,691, German Pat. No. 852,835, German Pat. No. 1,051,798, Journal of Metals, April 1964, pages 346–351).

It is also known to granulate fine coal in an eccentrically moving drum at an elevated temperature with an addition of binder so as to form lumps of coal. This process is not directed to a production of coke (German Pat. No. 885,088).

The disadvantages of the known processes of producing shaped coke articles reside mainly in that in most cases the pretreatment requires a plurality of stages and units, the press tools are subjected to high wear, a large amount of energy is consumed, and the carbonization products must be collected and processed by separate means. Further, as noted above, the processes are also restricted to certain grades of coal.

It is therefor an object of this invention to provide a novel method of producing shaped coke articles.

It is another object of this invention to provide a method of producing shaped coke articles which does not require any particular special grade of coal or other carbonaceous material.

It is a further object of this invention to provide a coked article producing process which utilizes the sensible heat of the volatile components of the carbonaceous starting material.

Other and additional objects of this invention will become apparent from a consideration of this entire specification including the claims hereof.

In accord with and fulfilling these objects, one aspect of this invention resides in the production of coke articles which are characterized by relative uniformity of size and shape. These coke articles are produced by pelletizing fine, granular, solid carbonaceous matter which is a mixture of highly caking coal and substantially non-caking coal. The pellets are heat hardened in a rotary kiln through the burning, with oxygen or air, of combustible volatiles generated from the pellets during heat hardening and from the volatilization of the volatiles content of high volatile carbonaceous matter which is also fed to the kiln. The carbonaceous product left after driving off the volatiles content of the high volatiles containing coal leaves the kiln and is thereafter used as the non-caking component of the pellets being fed to the kiln. The kiln is self sustaining as far as energy is concerned, and

may even be an energy generator depending upon the particular coals utilized. In any case, the kiln heats the cokable pellets at a rate of at least about 15° C. per minute to a maximum temperature of at least about 500 to 1,000° C. It is preferred to use a heating rate of up to about 50° C. per minute, most preferred to use a rate of at least about 30° C. per minute.

This process operates by mixing high caking coal and non-caking carbonaceous material with or without a binder, adding water, if necessary, to the mixture; pelletizing the mixture, suitably on a conventional drum or disk pelletizer; and then suitably drying the pellets, if needed, and pre-heating such by conventional techniques, as will be more fully explained below.

The pellets, suitably preheated and dried, are fed to a rotary kiln as are an oxygen containing gas and high volatiles containing carbonaceous matter, probably coal. In the kiln volatiles are generated from the pellets and from the high volatiles coal. These volatiles burn with the fed oxygen or air to provide the heat necessary to volatilize additional material, coke the pellets and render the high volatiles containing coal into a substantially non-caking material.

The hot gases leaving the kiln may be used as such or in an afterburner for drying and/or preheating the pellets before introduction thereof into the rotary kiln. If there is any sensible heat left in the kiln tail gases after such drying and/or preheating, such can be used for other heating tasks or merely vented.

The oxygen fed to the rotary kiln may be fed in the form of pure oxygen, air enriched with oxygen, oxygen admixed with other gases or the like. This oxygen is used to combust carbonaceous gases evolved from the pellets fed to the rotary kiln as well as carbonaceous gases evolved from the high volatiles carbonaceous material fed to the rotary kiln.

It is within the scope of this invention to predry the pellets but such predrying is merely preferred and is by no means necessary or essential.

It is further within the scope of this invention to utilize binders in the pelletizing operation. These binders may be organic or inorganic and may be carbonizable binders. The use of binders is preferred but it is neither necessary or essential to the practice of this invention.

The pellets generally consist of spherical bodies which have a substantially uniform diameter of substantially any predetermined size and are made on pelletizing disks or in pelletizing drums, these equipment are per se known for the manufacture of ore pellets. The carbonaceous pellets of this invention are substantially homogeneous bodies having substantially uniform properties.

Depending on the intended use, the pellets may be as large as about 50 millimeters in diameter. Even pellets of very small diameters, e.g. those used for adsorption purposes, can be made such that their size is most exactly controlled.

The solid carbonaceous matter usually consists of a mixture of cokable caking components and non-caking components. The caking components may amount to 5–75% of the mixture. The ratio of caking to non-caking components is selected with a view to the desired properties of the shaped coke pellet. Before the pelletization, the caking and non-caking components are preferably comminuted so that about 90% of the particles have a size below about 1 millimeter. The non-caking or low-volatile component used to produce the pellets is produced in the same rotary kiln as is the coke as noted above. It makes no difference whether single caking and/or non-caking components are used or whether a plurality of such caking and non-caking components respectively are used.

It is possible to use only non-caking carbonaceous matter in solid form and to use as the caking component organic carbonizable binders in an amount of up to about 25% related to the total mixture.

Organic binders in an amount up to about 25% or, depending on the required properties of the shaped coke, inorganic binders in an amount up to about 5%, or inorganic and organic binders together in appropriate amounts, may be added in all cases. Suitable inorganic binders include, e.g., bentonite, alkaline earth metal compounds, clays, etc. Suitable organic binders include, e.g. tar, mineral pitch, bitumen, pitch, molasses, starch, sulphite waste liquor, etc.

The water content of the pellets is suitably adjusted to about 5–30% of the addition of water before or during pelletization. Part of the water content may be replaced by an admixture of liquid binders or petroleum. The petroleum which is admixed may also be used as a fuel during the subsequent volatilization or carbonization.

The furnace used in the invention is preferably a rotary kiln. Other devolatilizing furnaces, including round or straight tunnel furnaces or rotary hearth furnaces may be used.

If the process is performed with a moving charge bed, the production of the non-caking component of the solid carbonaceous pellets is preferably carried out in the same devolatilizing furnace. The component which is to be devolatilized (that is the high volatile containing carbonaceous-coal material) is preferably charged into a rotary kiln by pneumatic or mechanical means and is distributed over the surface of the kiln bed over a considerable length of the kiln. The component to be devolatilized should have a smaller particle size than the pellets being cured, e.g., below about 25 millimeters. The devolatilized (non-caking) component is then separated, e.g. by screening, from the cured pellets discharged from the furnace and is recycled and added to the mixture to be pelletized. This non-caking component may be ground, if desired.

It is particularly preferred to distribute the component to be devolatilized over the kiln bed surface by pneumatic means via a trajectory parabola in a per se known manner such that the particles are distributed over a large area of the kiln bed, that is substantially the full width of the kiln bed and over a considerable length thereof. The particles are propelled different distances depending on their particle size, the smaller particles are propelled pneumatically a shorter distance than the larger particles because of their lower momentum.

In another embodiment of the invention, the pellets are charged into a bed of granular material or into a bed consisting of a mixture with solid granular material.

The granular material may consist of carbonaceous matter, sand, or iron ore. The iron ore is subjected to preliminary reduction in the devolatilizing furnace or is reduced to sponge iron therein. The granular material may alternatively consist entirely or in part of substances which combine with and remove sulfur, such as lime or dolomite, whereby the shaped pellets are desulphurized to a high degree.

The granular material preferably also simultaneously performs the function of heat carrier and is charged into the devolatilizing furnace at a temperature of at least 400° C. This procedure has the advantage that the pellets are more rapidly heated to the reaction temperature and the production of fines is thereby reduced.

When granular carbonaceous matter is used, it is preferably recirculated, e.g. after it has been separated by high-temperature screening from the pellets being discharged from the devolatilizing furnace and/or after it has been preheated. This procedure results in a devolatilized, non-caking material, of which a portion is used for admixture with other, caking, carbonaceous material being pelletized. It is therefore preferred that the use of dissimilar heat carriers is avoided.

The devolatilizing furnaces are preferably provided with burners and/or air supply pipes spaced along the length of the furnace which enable adjustment and regulation of the gas atmosphere and temperature through-

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out the length of the furnace as desired. The exact regulation of the gas atmosphere enables a partial or complete combustion in the furnace of part or all of the volatile constituents evolved during the devolatilization. Where partial combustion is accomplished, such may be succeeded by an afterburning of the remaining volatile constituents outside the furnace. In this way, substantially all of the energy values of all volatile constituents can be utilized.

Where a moving charge bed is employed, the green pellets may be charged into a granular bed entirely or in part through openings which are spaced along the furnace. These openings may include the burners or the air supply pipes. Any desired heating rate may be obtained in this way.

The process according to the invention may be carried out with the charge and gas atmosphere moving concurrently or countercurrently.

The main advantages of the process according to the invention are listed as follows:

The process enables a production of shaped coke having any desired properties, e.g. with respect to crushing strength, hardness, porosity, etc., from any solid carbonaceous matter by a suitable selection of the relative proportions of caking component and non-caking component, the heating conditions, the temperature and the furnace atmosphere. High volatile carbonaceous matter may be pretreated in the same plant. Caking coal may be replaced by other cokable components.

Carbonization products are not obtained. All by-products are obtained in such form that their energy is used either as the sensible heat in the flue gas from the furnace or in the form of combustible substances such as CO, H₂ or hydrocarbons.

The ash content of the pellets may be reduced by a flotation or the comminuted coal used to produce such pellets.

The pelletization may be used to control the porosity of the shaped coke within a wide range. A higher porosity can be obtained than in other, known processes of producing blast-furnace coke.

A substantial advantage of the process of the invention lies in the fact that it is able to produce coked pellets having a great part of its carbon derived from sources other than coking coal. This substitution is particularly advantageous in those cases where coking coal is not available or difficult to procure in the geographic or economic area of production. According to the process of the invention it is possible to produce coke pellets from mixed charges whose solid carbon content may consist substantially of non-coking carbonaceous materials, such as non-coking coal, peat, lignite or the like.

It is possible according to this invention to produce spherical coke bodies of uniform size, i.e. 10-15 mm. grain size or of even a narrower range of grain sizes from fine-grained carbonaceous materials. The fine-grained carbonaceous materials to be used in the instant process need not consist exclusively of coking coal but may also contain a considerably percentage of non-coking carbonaceous materials, such as non-coking, high-volatile coal, anthracite, coke fines, lignite, wood powder, or their charred products. When coal of good coking capacity is available, a content based on the coal mixture of approximately 15-30% by weight coking coal is generally sufficient.

A special advantage which is obtained by utilizing such mixtures of different carbonaceous materials is that the non-coking carbonaceous materials need not be ground to the fineness required for the pelletization of iron ores. If the carbonaceous materials are available in a fineness of less than 0.5 mm., it is sufficient that about 40% thereof have a grain size of less than about 60 microns. On the other hand, coking coal employed as a binder has to be ground to the fineness required for pelletization, i.e. to the fineness where 80% has a size of less than 40 microns.

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If the coking coal is not present in this fineness, its further grinding can be obviated by adding a bituminous binder, such as pitch tar, the spent liquor from cellulose production, molasses, or the equivalent thereof, during pellet production. It is, of course, also possible to incorporate further additives suitable for use in the production of the pellets and which will not interfere with their subsequent use. Thus, for example, when the coke pellets are intended for use in the reduction of iron ores, either in the rotary kiln or in the blast furnace, the addition of lime as a sulphur-binding agent and possibly for the scorification of silica, may be advisable. Moreover, the addition of other inorganic binders is permissible provided that such binders are not detrimental to the intended purpose of the pellets.

A further advantage of the process of the invention is that both the strength and the reactivity of the coke pellets produced may be adjusted to any desired value within wide limits. This is achieved in a most simple manner by pre-selecting a suitable hardening temperature. The higher the peak temperature to which the pellets are heated during their treatment in the furnace, the harder are the coke pellets produced. On the other hand, the lowering of the peak temperature improves both the porosity and the chemical reactivity of the coke pellets obtained. According to the invention, the charring temperature, which is conventionally about 500° C. for most coking coals, is sufficient as a minimum hardening temperature. However, it may be necessary to apply a peak temperature exceeding 1,000° C. for the production of particularly hard coke pellets.

As a heat carrier there may be used, for example, a bed consisting of coke pellets obtained by the instant process or a bed composed of raw coal which is simultaneously carbonized. The coal charged for carbonization can be one which is utilizable as a component in the production of the coke pellets according to this invention. In a preferred embodiment of the invention the production of coke pellets can be accomplished together with the pre-reduction of iron ores in such a way that a bed of unreduced iron ore pellets is used as a heat carrier. This iron ore is pre-reduced by the volatile materials evolved during the heating of the coke pellets, i.e. the iron ore reduction take place simultaneously with the coke pellet hardening.

The coke pellets produced in accordance with this invention may advantageously be used as charge constituents for furnaces. They are also suitable as reductants, or as particularly reactive carbonaceous materials for use in chemical reactions and as catalysts or catalyst components or substrates.

A particularly advantageous use of the coke pellets of the invention consists in impregnating the coke pellets with a liquid fuel, as for instance fuel oil, and utilizing the impregnated pellets as a combination reductant and fuel for the direct reduction of iron ores. The impregnation technique has been described in U.S. Pat. 3,425,824.

In the following examples, coke pellets were cured in a rotary kiln of 7.8 m. length and 0.5 m. I.D. equipped with 6 shell burners of known design distributed over the whole kiln length and appropriately supplied with gas and/or air. It was possible to operate the kiln in concurrent flow or countercurrent flow i.e. the gases could be passed through the kiln either in concurrent flow or in countercurrent flow with respect to the solids. If it was decided to operate the kiln in countercurrent flow, a central burner was additionally mounted at the kiln discharge (lower) end. This burner was so designed that it was possible to inject coal into the kiln pneumatically through a pipe centrally arranged in such burner.

The following coals were used in these examples:

high-volatile weakly caking coal,
high-volatile strongly caking coal,
anthracite.

The coal analysis was as follows:

TABLE I

	Anthracite	High-volatile coal	
		Weakly caking	Strongly caking
Moisture, wt. percent.....	1.1	1.85	1.05
Ash (775° C.), wt. percent.....	4.2	4.0	3.7
Fixed carbon, wt. percent.....	87.2	59.3	62.4
Volatile matter, wt. percent.....	7.5	34.9	32.8
Total sulphur, wt. percent.....	1.0	1.0	1.3
Free swelling index.....	0	4.5	8
Caking index (according to Damm).....	0	-----	23
Gross calorific value, kcal./kg.....	8,060	7,736	7,894
Net calorific value, kcal./kg.....	7,875	7,453	7,614

The anthracite and the strongly caking coal were ground for the pelletizing process without any other pretreatment and the weakly caking coal was previously charred.

The size distribution of the said coals after grinding, which was separately carried out for each coal, was as follows:

TABLE II

Grain size range, mm.	Size distribution, weight percent anthracite	High-volatile coal	
		Weakly caking (after charring)	Strongly caking
0.125-0.5.....	13.6	18.4	0
0.09-0.125.....	12.4	7.2	2.2
0.063-0.09.....	14.4	11.2	7.0
0.04-0.063.....	16.0	12.4	15.6
Minus 0.04.....	43.6	50.8	75.2
Total.....	100.0	100.0	100.0

The process according to the invention is described with particular reference to the following example.

EXAMPLE 1

60 wt. percent of strongly caking coal and 40 wt. percent of charred weakly caking coal of the above-mentioned grain sizes were mixed with 1 wt. percent bentonite as a binder and formed into pellets of 18-20 mm. grain size on a pelleting disc by addition of atomized water. The wet pellets contained 22% H₂O and their crushing strength was 2.0 kg./pellet which after drying increased to 2.9 kg./pellet. Their drop resistance was satisfactory: they only shattered after 6 drops from a height of 0.5 m. on a concrete floor.

The flow in the kiln was countercurrent. The charred weakly caking coal was produced by pneumatically injecting the weakly caking high-volatile coal into the kiln from the kiln discharge end thereof and was distributed over the kiln bed for a considerable length and then charred. The charred, devolatilized coal was recirculated to the mixing step and part was ground in a grinding plant to a grain size suitable for pellet production. The pellets produced from the admixed material were predried, for instance in a shaft-kiln, down to approximately 10% H₂O and then continuously charged into the bed of a rotary kiln heated to 700° C. by the combustion of gasses therein. The pellet charging was done by pipe means mounted on the rotary kiln shell at the feed (higher) end and at the center of the rotary kiln. Pellets at 240 kg./hour were fed through the pipe means. At the same time, 80 kg./hour of charring coke, of minus 5 mm. grain size were introduced into the kiln from the

higher end thereof and 120 kg./hour of slightly caking coal of minus 10 mm. grain size were injected with the incoming air into the lower end. The pellets were rapidly heated by internally generated heat to degasification temperature and then charred. The gases evolved from the pellets and from the raw coal injected were burned by the air supplied through the shell mounted burners and thus met the heat requirements of the process.

After a hardening temperature of 1,000° C. had been reached, the rotary kiln charge was discharged and then cooled in a cooling drum. The cured coke pellets so produced were screened to remove the +15 mm pellets whereas the undersize particles were recycled to mixing. The coke pellets contained 86% fixed carbon and had a crushing strength which ranged from 150 to 250 kg./pellet. The means strength was 205 kg./pellet.

EXAMPLE 2

63 wt. percent anthracite coal and 32 wt. percent strongly caking coal of the grain sizes indicated in Table II were mixed with 4.5 wt. percent hard pitch and 0.5 wt. percent bentonite as binders. This mixture was formed into pellets of 15-18 mm. grain size on a known pelletizing disc as described under Example 1. The pellets contained 19.8% water and their crushing strength was 1.54 kg./pellet which after drying increased to 2.1 kg./pellet. Their drop resistance was satisfactory: they only shattered after 6 drops from a height of 0.5 m. on a concrete floor.

The rotary kiln was operated in concurrent flow. The wet pellets were predried down to approximately 5% water and introduced into the rotary kiln at an intermediate location therein at a rate of 300 kg./hour into a preheated bed of 100 kg./hour high-volatile carbonaceous matter (HVCM) which was anthracite coal of minus 10 mm. grain size. The pellets were dried, devolatilized and hardened by heating to 800° C. The evolved gases were burned in order to heat the rotary kiln.

The coke pellets so produced were hot separated from the rest of the kiln discharge by screening and cooled by spraying with water. The minus 10 mm. fraction of the screen fall-through-fines were returned to the rotary kiln still hot while the remainder was cooled by spraying with water mixed with an appropriate amount of raw anthracite and then ground to the above-mentioned grain sizes.

The coke pellets had a crushing strength of 150 kg./pellet. They contained 89% fixed carbon and had a volume of voids of 43%.

In the following Examples 3 to 5 the rotary kiln had a length of 7.8 meters and an inside diameter of 0.5 meter. The rotary kiln was provided with burners, which were spaced along the length of the rotary kiln and were fed with air and/or gas as required. The rotary kiln was suitable for operation with the gases and the solid rotary kiln charge bed moving in concurrent or countercurrent direction respectively. The pellets to be coked were preheated with the exhaust gases from the rotary kiln or with additional burners, depending on whether the rotary kiln was operated with countercurrent or concurrent flows in order to dry and preheat them. If the heat content of the exhaust gases from the rotary kiln was utilized for heating the grate, it was possible to adjust the gas temperature and the composition of the gas to the conditions required at any time by a supply of air and an after-burning of the combustible constituents contained in the exhaust gases from the furnace. The rotary kiln was also provided with a pneumatic device for charging coal. With the device, coal was blown into the rotary kiln by means of coal or preheated air or of exhaust gases or fuel gases in a concurrent flow relative to the gases in the rotary kiln. With concurrent flow operation, the blowing device was incorporated at the receiving end of the rotary kiln.

The coals used in these examples were a highly caking coal, a slightly caking coal, and an anthracite coal.

The properties of these various coals are stated in the following Table III:

TABLE III

	Coal		
	Anthracite	Slightly caking	Highly caking
Moisture, percent by weight.....	1.1	1.85	1.05
Ash (775° C.), percent by weight.....	4.2	4.0	3.7
Fixed carbon, percent by weight.....	87.2	59.3	62.4
Volatiles, percent by weight.....	7.5	34.9	32.8
Total sulfur, percent by weight.....	1.0	1.0	1.3
Free swelling index.....	0	4.5	8
Caking index (according to Damm).....	0	-----	23
Upper calorific value, kcal./kg.....	8,050	7,736	7,894
Lower calorific value, kcal./kg.....	7,875	7,453	7,614

Pitch, waste sulphite liquor and bentonite were used as binders in preparing the pellets. The pitch was ground in a dry state so that about 50% thereof was less than 40 microns particle size.

Typical particle size distributions of the various carbon sources are stated in the following Table IV:

TABLE IV

Particle size range, mm.	Particle size distribution, percent		
	Anthracite coal	Dry-distillation coke	Caking coal
0.125-0.5.....	13.6	18.4	0
0.09-0.125.....	12.4	7.2	2.2
0.063-0.09.....	14.4	11.2	7.0
0.04-0.063.....	16.0	12.4	15.6
Less than 0.04.....	43.6	50.8	75.2
Total.....	100.0	100.0	100.0

EXAMPLE 3

Highly caking coal as set forth in Table IV was used in this example. The non-caking component required for pelletizing was produced in the rotary kiln by a dry distillation of the caking coal. This caking coal, in a particle size below 12 mm., was pneumatically charged in to the upper end of the rotary kiln, which was operated with concurrent flows. The coal was distributed over about 1/2 of the total length of the kiln and substantially the full width thereof. The material which was discharged from the rotary kiln was screened with part of the resultant non-caking product directly returned into the rotary kiln and the rest ground to a particle size which was suitable for pelletizing, such as is stated in Table IV for dry-distillation coke.

The mixture to be pelletized was composed of 50 parts caking coal, 50 parts dry-distillation coke (non-caking component), 5 parts pitch and 1% bentonite. The mixture was shaped into pellets having a size of about 25 mm. The moist pellets contained about 20% H₂O. They had a crushing strength of about 4 kg. per pellet. This figure was increased by drying to 7 kg. per pellet.

The moist pellets were continuously charged onto a travelling grate in a layer about 25 cm. high and were dried with the aid of hot gases. The dried pellets at 150° C. were charged, while retaining their sensible heat, into the rotary kiln and were heated therein to a hardening temperature of 1,000° C. together with the recycled dry-distillation coke. During this treatment, the pellets were themselves subjected to dry distillation, coking and hardening.

The gases evolved by the dry distillation of the pellets and of the HVCM were partly burned in the kiln with the aid of air producing a highly reducing atmosphere. The combustion products and the coke pellets did not react.

About 240 kg. per hour of pellets were charged onto the grate, dried and then charged into the rotary kiln together with the circulating dry-distillation coke. 140 kg. per hour crude HVCM were simultaneously charged to the kiln concurrently with the gases.

The material discharged from the kiln was screened to separate the coke pellets which had been produced above a size of 15 mm. from the other material discharged from

the kiln after said material had been cooled in a cooling drum. 60 kg. of the dry-distillation coke were directly re-circulated into the kiln. The remainder was ground and used as a non-caking component for pelletizing.

The coke pellets had a size of 18-22 mm. and a mean crushing strength of 200 kg. per pellet. They contained 85% fixed carbon and less than 1% volatiles. Their void volume was about 45%. The hot effluent gas from the kiln still contained combustible constituents and was directly fed to a boiler plant for the generation of steam.

EXAMPLE 4

In contradistinction to Example 3, the non-caking component consisted of 70 parts of anthracite, which was mixed with 30 parts of the highly caking coal, 10 parts of pitch and 2% bentonite. This mixture was similarly pelletized. The pellets had a size up to 40 mm. They contained 18% H₂O and had a mean crushing strength of 5 kg. per pellet. This figure was raised to above 10 kg. per pellet after the pellets had been dried.

The rotary kiln was operated with concurrent flow. The pellets were dried and preheated on a grate. They were charged into the rotary kiln after they had reached a temperature of about 350° C. The granular material charged into the kiln was sand, which was recycled at an elevated temperature into the kiln after the discharged product had been screened at an elevated temperature to remove the coked pellets from the material discharged from the kiln.

The pellets were heated to 800° C. and were coked and hardened by this treatment. The gases evolved during the coking of the pellets were mixed with the aid of added air, as described in Example 3, and used for heating the rotary kiln, which was provided with a central burner at its charging end.

The hot coke pellets were cooled by spraying water onto them. They had a crushing strength of 180-220 kg. per pellet and contained more than 90% fixed carbon.

EXAMPLE 5

In this example, 50 parts of the slightly caking coal, 50 parts of dry-distillation coke obtained in the same kiln operation and 10 parts of pitch and waste sulfite liquor were mixed together and pelletized. The green pellets contained about 3% waste sulfite liquor on a dry basis. A pellet size of 30 mm. was utilized in this example. The pellets had a crushing strength of about 5 kg./pellet in the green state and above 12 kg./pellet in the dry state.

The still moist pellets were charged into a rotary kiln to form a thin layer therein, and this layer was covered with a layer of slightly caking coal having a size below 5 mm. During one cycle, the pellets were dried and heated to the coking temperature. The gases evolved by the dry distillation of the pellets were used as a fuel for heating and were burned with the aid of air which was blown in. The gases obtained by drying were separately withdrawn.

The coke pellets were screened from the fine-grained non-caking components. The pellets were partly caked to the dry-distillation non-caking component and to each other and had a crushing strength of about 140 kg. per pellet.

The dry-distillation coke was ground as described above, and was then mixed with feed coal and binders, pelletized and then fed to the kiln as aforesaid.

What is claimed is:

1. Process for producing coke bodies in a rotary kiln comprising:

- producing pellets of caking carbonaceous material and non-caking carbonaceous material of predetermined size;
- feeding said pellets into a rotary kiln;
- feeding an oxygen containing gas to said kiln;
- feeding a high volatiles containing carbonaceous material to said kiln;
- coking said pellets, evolving combustible gas from said pellets during said coking, and evolving com-

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- bustible gas from said high volatiles containing carbonaceous material in said kiln by subjecting such to a heating rate of at least about 15° C. per minute to a maximum temperature of about 500 to 1,000° C.;
- (F) burning at least a portion of the gas evolved in step E whereby to provide sufficient heat for said kiln operation;
- (G) recovering from said kiln coked pellets and non-caking component;
- (H) separating said coked pellets from said non-caking component;
- (I) admixing at least a portion of said non-caking component with said caking carbonaceous material and
- (J) feeding said admixture of step I to step A.
2. Process as claimed in claim 1 wherein said admixture has about 5 to 30 weight percent of water added thereto.
3. Process as claimed in claim 1 wherein said pellets are subjected to predrying prior to said heat hardening.
4. Process as claimed in claim 1 including providing a binder in combination with said admixture.
5. Process as claimed in claim 4 wherein said binder is organic.
6. Process as claimed in claim 4 wherein said binder comprises materials having a coking value.
7. Process as claimed in claim 4 wherein said binder is at least one member selected from the group consisting of tar, mineral pitch, bitumen, pitch, molasses, starch and sulfite waste liquor.
8. Process as claimed in claim 4 wherein said binder is at least one member selected from the group consisting of bentonite, alkaline earth metal compounds and clays.
9. Process as claimed in claim 1 wherein said heating rate is about 30–50° C. per minute.
10. Process as claimed in claim 1 wherein said admixture comprises about 15–30% coking coal.
11. Process as claimed in claim 1 wherein said pellets have a diameter of up to about 50 millimeters.
12. Process as claimed in claim 1 wherein said admixture comprises non-caking components and about 5–75% caking components.
13. Process as claimed in claim 12 wherein about 90% of the non-caking components of said carbonaceous matter are particles having a diameter up to about 1 millimeter.
14. Process as claimed in claim 12 wherein said caking components are particles having a diameter up to about 1 millimeter.
15. Process as claimed in claim 5 wherein organic binders are utilized in a proportion up to about 25% based on said carbonaceous matter.
16. Process as claimed in claim 4 wherein inorganic binders are utilized in a proportion up to about 5% based on said carbonaceous matter.

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17. Process as claimed in claim 1 wherein said high volatiles containing carbonaceous material is fed to said kiln in a particle size of up to about 25 mm.
18. Process as claimed in claim 1 wherein said pellets are charged into said kiln under such conditions that said pellets are admixed with a solid granular heat transfer material therein.
19. Process as claimed in claim 18 wherein said granular material comprises carbonaceous solids.
20. Process as claimed in claim 18 wherein said granular material comprises sand.
21. Process as claimed in claim 18 wherein said granular material comprises iron ore.
22. Process as claimed in claim 18 wherein said granular material comprises sulphur-combining material.
23. Process as claimed in claim 18 wherein said granular material is present in said kiln upon introduction of said pellets and is preheated to at least about 400° C.
24. Process as claimed in claim 18 wherein said granular material is removed with said heat-hardened coke pellets, separated from said coked pellets and recycled to said kiln.
25. Process as claimed in claim 24 wherein said granular material is separated from said coke pellets by screening.
26. Process as claimed in claim 1 wherein air is introduced into said furnace at a multiplicity of points.
27. Process as claimed in claim 1 wherein the solids in said kiln and gas fed thereto move concurrently.
28. Process as claimed in claim 1 wherein the solids in said kiln and gas fed thereto move countercurrently.
29. Process as claimed in claim 1 wherein solid feed material to said kiln is fed onto a bed thereof by propulsion means such as to introduce said solid feed material onto the bed of the kiln in a trajectory proportional to the particle momentum.

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201—20, 23, 22, 27, 33; 264—117, 29

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(5/69)UNITED STATES PATENT OFFICE
— CERTIFICATE OF CORRECTIONPatent No. 3,560,346 Dated February 2, 1971Inventor(s) GÜNTER HEITMANN

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

The inventor's name should be changed to --Günter Heitmann--

Column 1, line 1, "bokies" should be corrected to --bodies

Column 1, line 16, "volatilec" should be corrected to read
--volatile--

Column 1, line 19, "coking" should be corrected to read
--caking--

Column 2, lines 32, 40, 42, 45, 53 and 55, "articles" should
be corrected to read --particles--

Column 3, line 8, after "operates" insert --with reference
to Fig. 1--

Column 3, line 27, "tail" should be corrected to read --was

Column 4, line 39, after "a" insert --relatively--

Column 8, line 70, "coal" should be changed to read --cold

Signed and sealed this 18th day of January 1972.

[(SEAL)]
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Acting Commissioner of Patent