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## PRODUCTION OF USEFUL COMBUSTIBLE GASES FROM CAKING BITUMINOUS FUELS

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The present invention relates in general to a process for the production of useful gases from finely divided coking coal and in particular to a process of this kind in which there is associated with the production of useful gases a recovery of metals or metal alloys by first of all coking a mixture of coal and fine ore with the formation of fuel gas and then smelting the resulting coke.

It has already been proposed to carry out the dry distillation of bituminous coal in suitable coal distillation ovens, for example horizontal chamber ovens by first of all making a mixture, capable of being poured, of fine coal and fine ore and then coking this in the coking chamber under the known conditions. On the one hand there is formed a coke oven gas and on the other hand a coke which contains the metal admixed, in the form of ore, partly in elementary form, and partly in partly reduced form and partly in the form of the original ore. This known proposal primarily served to smelt the fine ore not in itself capable of use in a blast furnace.

The metalliferous coke produced in this way—that is, in the case of admixed iron ore, ferrous coke, hereinafter referred to as iron coke—can, so long as it has a sufficient resistance to pressure and sufficiently coarse texture, be further treated in normal blast furnaces, that is in a reduction and smelting furnace with a considerable shaft height. As a result there is formed in addition to iron and slag, a gas which although combustible has a heating value which is in many cases insufficiently large for industrial purposes.

The gasification of the iron coke produced in the known manner in a gas producer without liquefaction of the ash whilst producing in itself a gas of higher heating value than blast furnace gas cannot be considered for two reasons, firstly because in the usual coke gas producers (as for example rotary gas generators or the like), the metal or ore would mix with the ash so that a costly separation of the iron from the ash would have to be carried out. The second reason why iron coke could not be introduced into the normal coke gas producers lies in the fact that the generator gas recovered in such a process is higher in price per calory than the normal coke oven gas resulting from the distillation of coal so that it would be economically disadvantageous to substitute for example coke oven gas by the generator gas produced in this way, for the purpose of heating the coking ovens.

The invention follows the idea of recovering by gasification, from a metalliferous coke, on the one hand useful fuel gas the heating value of which is higher than that of blast furnace gas, and on the other hand the metal separately from the slag. This idea is carried into effect by producing combustible gases from the coke obtained by coking a mixture of finely divided coking coal and fine ore in a low shaft furnace constructed as a tapped gas producer (slagging generator), by gasification by means of oxygen and, if required, endothermically, reacting gasification media with reduction of the ore contained in the coke and liquefaction of the metal and the ash, the resulting metal and the slag being separately withdrawn in the fluid state at intervals or continuously. The heat-

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ing value of the fuel gas produced in the shaft furnace constructed as a tapped gas producer is about 1150–1200 kcal./nm.<sup>3</sup> and is therefore considerably higher than that of the normal blast furnace gas from a blast furnace. On the other hand there is obtained with this type of gasification of the iron coke a raw iron which is qualitatively of a high value and which can be further treated in accordance with the usual methods of iron smelting.

The distinguishing characteristic of the process according to the invention thus lies in the use of a shaft furnace, low in comparison with a blast furnace, in the manner of the known tapped gas producer. Oxygen is here to be understood as air or air enriched with oxygen or in some cases even oxygen of high concentration. The gasification medium “oxygen” can be injected into the tapped gas producer at normal temperature, preferably however in the preheated condition. There may be preferably employed as endothermically reacting gasification media steam, carbon dioxide or a mixture of both, preferably in a highly preheated condition.

Within the scope of the invention there is to be understood as fine ore a finely granular to pulverulent ore or ore fraction which is recovered from the naturally occurring ore by sieving, flotation or elutriation.

The invention further provides for separating from the produced ore or metalliferous coke, before gasification, the fully granular coke fraction, as this could give rise to difficulties in operation of the tapped gas producer, and for mixing this so-called fine grain with further quantities of coal and fine ore and coking it.

In order to increase the pouring weight of the coal-ore mixture the invention further provides for adding to this mixture, before coking, heavy mineral oil or tar oil, pitch, asphalt or the like in finely divided form, in a quantity of about 1–3 per cent by weight. On account of the cracking of the oil in the coking of the coal-ore mixture the heating value of the resulting coke oven gas is increased.

The fuel gas produced in the tapped gas producer from the metalliferous coke can be directly employed. If however the metalliferous coke is gasified with oxygen and preheated steam, then there may be produced, by carburetting or methanisation of the gas produced, a rich gas which has a town gas quality. This gas can then preferably be used in admixture with the coke oven gas resulting in the coking of the coal-ore mixture.

The metalliferous coke can then be converted in the above stated manner into gas on the one hand and metal on the other, in the shaft furnace constructed as a tapped gas producer.

In cases where there is used, as the starting material for the manufacture of the metalliferous coke, coals which do not in themselves give coke capable of use for the blast furnace or the gas producer, the invention proposes subjecting such coals to a heat treatment at about 100° or more, in the presence of or with the exclusion of air, before coking and after the admixture of oxidising ores of the highest oxidation stages, particularly iron, nickel or copper ores. For example if one uses a coal rich in bitumen, which does not give a hard but a frothy or splintery coke, then it is preferable to add iron ore of the type Fe<sub>2</sub>O<sub>3</sub> in a quantity of less than 3%. This coal-ore mixture is then heated for a certain period to temperatures above 100°. The coal so treated then gives a coke sufficiently strong for smelting and other purposes. If however there is used for the manufacture of the metalliferous coke caking and in particular “driving” coals, it is preferable to increase the addition of Fe<sub>2</sub>O<sub>3</sub> to above 3%. The succeeding heat treatment then effects a reduction of the tendency of the coal to rise.

The invention may in particular be employed with economic advantage if the gas resulting from the gasification of the ferrous coke serves as the under-firing gas

for the coal distillation oven effecting the coking of the coal-ore mixture. It is known that the coal distillation oven itself is a heavy consumer of the coke oven gas produced by it when the under-firing of this distillation oven is covered wholly or partly by the total quantity of coke oven gas produced, so that only the surplus portion of gas is available for other purposes.

Suggestions have therefore not been lacking for using for the under-firing of the coal distillation oven another suitable fuel gas, particularly a gas with a smaller heating value (producer gas) and thereby freeing considerable quantities of valuable coke oven gas for other uses.

The blast furnace gas with a heating value of about 900-1000 kcal/nm.<sup>3</sup> forms a substantial source for the under-firing producer gas. With a suitable preheating of both the blast furnace gas and the air for combustion the blast furnace gas is suitable as under-firing gas and can be so employed. The employment of blast furnace gas as under-firing gas is however associated with the proximity of a blast furnace supplying the blast furnace gas, so that the costs of conveying the gas from the blast furnace to the distillation oven battery do not give rise to an increase in the operating costs of the distillation oven battery, which cannot be borne.

Where blast furnace gas is not available one is thrown back on the use of generator gas. The recovery of a gas, capable of being used for under-firing purposes, direct from coal in generators is however tied up with a very restricted range of types of coals, namely coals which are not or not substantially, caking. Moreover the production of a producer gas direct from coal in generators is in general always attended with a loss of coke oven gas and valuable side products, particularly benzene hydrocarbons. Moreover the generator gas from coal contains in addition to tar and other heavy hydrocarbons nitrogen oxides which may give rise to gummy deposits in the gas pipes and regulating members.

The known coke gas generator certainly supplies a gas which is in itself capable of use for the under-firing of distillation ovens, but the production costs of the producer gas produced from the usual coke in generators, in relation to the same heating value as coke oven gas, are so high, that the employment of this gas as an underfiring gas leads to an increase in the price of the coke oven gas which makes it no longer profitable and economic. Moreover the quantity of coke of particle size suitable for the generator operation which can be recovered from normal coke, intended for smelting purposes, by sieving, is not large enough to cover the generator requirements so that it is necessary to break valuable smelting coke. As a result the occurrence of coke slack is undesirably increased.

The present invention solves, in a further form of application, the problem of freeing a maximum quantity of coke oven gas from coal through total substitution of producer gas in place of the proportion of coke oven gas hitherto required for the under-firing of the coke oven and follows the main idea of associating, with the coal distillation oven for the production of the under-firing gas, a shaft furnace constructed in the manner of the tapped gas producer—hereinafter shortly referred to as an "iron coke gas producer," that is, a generator in which by liquefaction of the residue from the gasification a lump coke is produced which contains a considerable proportion of metallic iron or reduced iron ore. The functional connection between the coal distillation ovens on the one hand and the coke gas generators supplying the under-firing gas for these ovens on the other hand, are achieved through the following features.

(1) The production of the under-firing producer gas takes place in a coke gas producer with liquefaction of the residue whilst however the manner of operation of this coke gas producer working with the liquefaction of the residue is characterised in that there is supplied to the coke gas producer a coke which contains the metallic

iron in a quantity between 20 and 50 per cent by weight, i. e. the coke gas producer for the production of the under-firing gas is operated so that there is produced in it a substantially increased quantity of fluid iron.

(2) The coke containing the metallic iron in a quantity of 20 to 50 per cent by weight is produced in the coal distillation ovens which are functionally connected with the aforesaid coke gas producers insofar as the coke gas producer supplies the under-firing gas for these coal distillation ovens. The production of the ferrous coke takes place in normal coal distillation ovens, e. g. horizontal chamber coke ovens, by the coking of a loose coal-ore mixture, i. e. a non-briquetting mixture a certain proportion of mineral oil or tar oil or the like being advantageously added to this coal-ore mixture before coking and this, as a kind of lubricant, increasing the weight of coal-ore mixture which can be poured in and therefore also increasing the amount of coal which can be introduced into the coking chamber.

(3) The grain sizes of coal and ore are so determined in relation to each other that the grain size of the ore fraction is smaller than the grain size of the coal fraction, so that the admixture itself of a comparatively large quantity of iron ore to the coking coal of coarser grain size does not, or does not substantially reduce, namely only by about 3-5%, the amount of coal which can be poured into a coking chamber.

(4) The ore to be admixed with the coking coal before coking is one which below the temperature of the formation of coke does not, or does not noticeably affect the ability of the introduced coking coal to cake during the coking operation. Ores chosen in accordance with the invention are therefore preferably those of the ferrosoferric oxide ( $\text{Fe}_3\text{O}_4$ ) type. In the coking of the coal-ore mixture a reduction of the iron ore takes place substantially by direct reduction, i. e. by free carbon, whilst on the other hand the indirect reduction, i. e. by carbon monoxide and, possibly hydrogen, if it takes place at all, is of subordinate importance. In the direct reduction of the iron ore there is formed, in addition to a small quantity of carbon dioxide, chiefly carbon monoxide, so that the total quantity of gas from the coke oven gas produced from the coking coal and the carbon monoxide resulting from the reduction of the iron ore are mixed together and form a gas mixture the volume of which is greater than that of the distillation gas resulting from the same mixture of unmixed coal. The heating value of this mixture gas is certainly slightly reduced by the admixture of carbon monoxide resulting from the direct reduction, but the total heat energy of the produced gas, in relation to the unit weight of introduced coal, is considerably greater than with a charge of unmixed coal.

The admixture of considerable quantities of iron ore, particularly high percentage iron ore, to the coking coal according to the invention also acts advantageously on the coking operation insofar as on account of the higher specific heat conductivity of the ore in relation to the coal the heat conductivity of the coal-ore mixture is correspondingly greater, so that the heat given up by the chamber walls travels more quickly into the furnace charge. The absolute period of reaction for a given volume of a coal-ore mixture with unchanged heat requirements, i. e. constant heating wall temperature, is therefore not increased by the time which would occur with unmixed coal by an increased endothermic reaction in the chamber charge, but by a considerably smaller time, in other words, the reaction time with a coal ore mixture of the kind described does not increase in proportion to the increased charge weight of a filling of the chamber. As a result, there is a relative shortening of the coking time of the coal-ore mixture. It makes it possible, with a comparatively small increase in the chamber wall temperature to bring the reaction time for a coal-ore mixture composed in accordance with the inven-

tion, to the same absolute value as the reaction time for the same volume of unmixed coking coal.

It has further been ascertained that even with the admixture of such quantities of iron ore with the introduced coal that the iron fraction in the iron coke formed amounts to up to 50%, a coke is formed which remains in lumps and which fully meets the requirements in lump strength of coke in coke gas producers, particularly if there is used an iron ore which does not or does not noticeably influence the caking power of the coal during coking.

The fact that with the coking material from the first stage of the process in its employment as fuel for the generators, smaller demands are made as regards strength than with blast furnace coke, has the result that the process according to the invention can also be carried out with the employment of caking gas coals and gas flame coals or the like which were not hitherto regarded as coking coals in the field of iron production. Poor fat coal is also capable of use within the scope of the process according to the invention so long as it is employed with such an addition of coking coal, particularly gas coal and gas flame coal, that upon coking there is formed a lump coke suitable for supplying to the generator.

The coke gas producer operated with iron coke produced in this manner and working with liquefaction of the residue, supplies in addition to the gas intended for the underfiring, a considerably increased quantity of iron that is a comparatively high value product, whereby the costs of production of the underfiring gas are so considerably reduced that the total substitution of the coke oven gas previously employed for the underfiring by generator gas is possible without any appreciable economic load on the price of the coke oven gas.

The general rule of this embodiment of the invention, namely that the grain size of the ore fraction in the coal-ore mixture must be smaller than the grain size of the coking coal fraction is advantageously put into practice by having about 80% by weight of the coal fraction with a grain size below 5 mm. and preferably below 2 mm., whilst the grain size of the ore fraction to 100% by weight is preferably selected below 1 mm. as exists in the so-called "schlich" which is found in the preparation of ore.

The ratio by weight of the mixture of the ore and coal may be varied within comparatively wide limits. The fraction of the coal in the coal-ore mixture is preferably chosen at between 50 and 80% by weight, preferably 65-70% by weight and that of the ore fraction is selected so that after coking there exists in the iron coke an iron content of 20 to 50% by weight after coking, preferably about 30% by weight.

It has been found that coal and ore particularly if the latter exists in the form of magnetite mix particularly well with one another if both components are in a moist state, the coal preferably with about 10% and the ore with about 5% moisture. In such a case the fine ore grains adhere so firmly to the coarser coal grains that stable mixtures can be manufactured by a comparatively simple mixing operation.

The addition of mineral or tar oil to the coal-ore mixture also proposed by the invention preferably amounts to about 1-3 per cent by weight. In addition to facilitating the mixing of the solid components of the mixture the addition of oil has also the favourable effect that the heat value of the resulting coke oven gas which may in itself drop somewhat through the formation of carbon monoxide by the direct reduction of the ore fraction, can again be restored to the previous value. In many cases an increase in the addition of oil beyond 3% may be of significance for the further increase of the heat value of the coke oven gas produced. The oil or the like is according to the invention advantageously first of all mixed with the iron ore, this mixture then being combined with the coal.

For recovering an iron coke suitable for generators when coking the coal-ore mixture according to the invention the chemical nature of the iron ore introduced is, as already stated, of importance. If iron ore with a comparatively high oxygen content, e. g., of the  $\text{Fe}_2\text{O}_3$  or  $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$  (red iron ore and brown iron ore) is used then, with the conditions of normal coke oven operation there can be produced from certain types of coal an iron coke, comparatively poor in iron, of sufficient lump strength. The permissible addition of ore then generally lies below about 5 or 10% by weight. The reason for this phenomenon lies in the fact that iron ores with high oxygen content have such a strong oxidising and ageing effect on the coal, even at temperatures below the formation of coke that the ability of the coal to cake is extensively destroyed. On the other hand, it has been found that iron ores of the  $\text{Fe}_3\text{O}_4$  type (e. g. magnetite) are so non-reactive that even with ore admixtures of 50% and more an iron coke is formed which is of a lump strength sufficient for delivering to a generator.

Instead of magnetite it is in some cases also possible to use ore of the  $\text{Fe}_2\text{O}_3$  type if this is subjected to a thermal pre-treatment, e. g. by roasting.

Siderite ( $\text{FeCO}_3$ ) is in general less suitable since it contains less iron and impairs the heating value of the distillation gas by yielding  $\text{CO}_2$  during coking.

It is advantageous to operate the gas producer with pre-heated air for gasification, the heat content of the generator gas produced being utilized for pre-heating the air blast.

The production of the underfiring gas in one or more tapped generators associated with a coke oven battery and operated and charged according to the invention has, in comparison with the smelting of coke and lumpy ore in a blast furnace of the usual construction, the advantage of a better and simpler adaption of the gas producer to the underfiring gas requirements of the coke over battery. The very reactive iron coke permits a comparatively rapid change of the gas output of the gas producer, whilst the comparatively small shaft height of the gas producer compared with the normal blast surface assists the elasticity of operation. Also the production of the underfiring gas in a number of gas producers working in conjunction with the same coke oven battery permits a relatively trouble free coking operation by the switching in or out of individual gas producers.

It is well known that the demand for coke oven gas in industry is not constant but is subjected to certain fluctuations which particularly at weekends reach an absolute minimum. The quantity of coke oven gas is then greater than the requirement and indeed the excess amount is generally also greater than the storage space available. In such a case—assuming an unchanged gas output of the coke oven battery, coke oven gas may be primarily employed for underfiring, i. e., the gas output of the gas producer must be correspondingly reduced by variation of the charge whilst, however, proceeding in such a manner that the gas producer can again be brought in a short time to the full gas output. The relatively very cheap producer gas of low heat value which then remains may be used for any purpose, e. g. for the heating of steam boilers. In order to permit this alternating operation the gas producer is previously provided with a corresponding shaft height.

In the case where the resulting coke oven gas is disposed of in its total output in normal circumstances as main gas, then, in periods of a smaller demand for coke oven gas a part of the coke oven gas can be diverted, before compression to the main gas pressure, and use as under-firing gas. With such a method of operation however this diverted coke oven gas fraction would not be directed through the benzene recovery plant, so that the valuable benzene hydrocarbons contained in the diverted

coke over gas fraction would be burnt therewith in the under-firing if a separate benzene washing was not provided for this part. In order to avoid this disadvantage the total quantity of coke oven gas produced in the distillation oven is constantly compressed, independently of the requirement for coke oven gas, and is then subjected to benzene washing without reduction of pressure, the coke oven gas fraction not required then being diverted for under-firing purposes. The total compression work and the steam required therefor may moreover be produced from the very cheap producer gas which the gas producer then supplies. In this way the costs for the compression work in periods of small coke oven gas requirement, may be reduced to a minimum.

It has been found that the manufacture of the under-firing gas from iron coke for the purpose of releasing the greatest possible quantity of coke oven gas has also advantageous economic effects in another direction.

The coke intended for a blast furnace of the usual kind is generally made from fat coals. This certainly produces a coke of sufficient lump strength but the proportion of grain sizes capable of use in blast furnaces is comparatively limited. The fat coals generally employed for smelting coke production supply a coke which consists of about 60% of coke particles greater than 80 mm., whilst 36% of the small coke lies between 10 and 80 mm. and 4% of coke slack below 10 mm. Of these 3 fractions only the first named fraction can be used as blast furnace coke, whilst the coke fraction between 10 and 80 mm. in the form of broken coke must be given up to other heat utilisation means, i. e. cannot be used for the actual iron production in the blast furnace. The slack fraction is commonly used in sintering plants as a sintering fuel.

It has been found that in the production of iron coke with the use of coals rich in gas or even other sorts of coal which had not been used hitherto for the production of smelting coke, it is possible to obtain a ferrous coke which is also of sufficient lump strength and coarseness of grain for blast furnace purposes. For example there may be produced from a gas-rich coal of a given composition which is coked with iron ore to form iron coke, a coke which contains at least 60% of iron coke in solid lumps with a grain size of 60 mm. The fraction of coke between 10 and 60 mm. amounted to 33% whilst the coke slack fraction below 10 mm. amounted to about 7%. The coarse iron coke above 60 mm. is solid that it can be introduced into normal blast furnaces. The coke fraction between 10 and 60 mm. which cannot be directly used with the normal coke for the production of iron in blast furnaces, is according to the invention, gasified in tapped gas producers with the production of iron, useful gas being produced in addition to iron. It can thus be said that with the iron coke made by the process of the invention, if its coarse portions above 60 mm. are supplied to the blast surface and only the portions between 10 and 60 mm. to the coke gas producer, practically all of the solid carbon introduced in the manufacture of iron coke can be utilized for the production of iron. The iron coke slack in quantities up to 7% can be used in the usual way as a sintering fuel the iron content, as iron coke, benefiting the sintering material. It is moreover preferable to employ in the sintering plant a fine ore ( $\text{Fe}_2\text{O}_3$ ) which on account of its high oxidising power cannot immediately be employed for the manufacture of iron coke in normal coke ovens.

According to a further feature of the invention the coarse fraction above 60 mm. resulting from the production of the iron coke is introduced directly into the blast furnace whilst the iron coke gas generator only receives the middle grain sizes between 10 and 60 mm.

The introduction of iron coke directly into the blast furnace provides in some circumstances a considerable advantage for the operation of the blast furnace. It is

known that the blast furnace is generally arranged according to the coke with which it is charged and that the addition of ore is adapted to the fluctuations in the quality of the coke. If however, in accordance with the invention there is introduced into the blast furnace, in addition to the normal coke, coarsely granular iron coke, then there is the possibility of controlling fluctuations in blast furnace operation not only by the addition of ore but also by regulation of the mixture ratio between normal coke and iron coke. The operation of the blast furnace may in some cases therefore be carried out more elastically since it is independent of the given quality of coke.

The direct introduction of iron coke into the blast furnace enables in addition the smelting output of the blast furnace to be increased since the iron, already pre-reduced, contained in the iron coke, reduces the fuel charge per ton of raw iron and also because the iron coke has a higher reducing power compared with normal coke, whereby the fuel consumption per ton of raw iron is reduced and the output of the blast furnace is accordingly increased.

Fluctuations in the requirements of the blast furnaces for iron coke may be equalised by converting a certain percentage of the coarse iron coke fraction into generator gas on the one hand and raw iron on the other, in the coke gas producer, with preliminary breaking of the iron coke if required.

A further advantage of the employment of iron coke in the blast furnace is given by the fact that as a result of working with iron coke the volume ratio of coke to additions, which is increased in favour of the coke in many cases also enables the fraction of the poor ores to be smelted to be increased.

The iron coke resulting from the coking of the coal-ore mixture which is worked up into under-firing gas on the one hand and raw iron on the other is distinguished, it has been found, from normal coke not only through its iron content but also through its reactivity which in some cases is considerably greater. This considerably increased reactivity permits not only a direct introduction of the iron coke with a sufficient grain size into the blast furnace but also permits the reacting of the iron coke directly in the coking chamber with certain gaseous materials.

It is known to feed steam into coke chambers filled with degasified coke in order to convert a part of the steam into water gas by means of the glowing coke. Apart from the fact that only a very restricted quantity of steam can be reacted in this way, it has been shown that the hot steam in some cases exerts an unfavourable effect on the chamber walls. It has also been proposed to introduce water gas into such coking chambers.

A further feature of the invention consists in introducing carbon dioxide into the coking chambers filled with completely degasified iron coke. The carbon dioxide which with normal coke and the temperatures obtaining in the coking chambers would only react in a very small degree with the formation of carbon monoxide, reacts with the very much more reactive iron coke so that a considerably increased quantity of carbon monoxide is formed whereby the total quantity of gas released in the coking chamber is increased.

The delivery of the carbon dioxide into the coking chamber filled with iron coke can be effected in the known manner, e. g. by passages which are provided in the base or in the walls of the chamber. It is also possible to introduce into the chamber charge special pipes which are provided with holes through which the carbon dioxide gas can be brought into contact with the glowing iron coke.

The carbon dioxide to be introduced may be taken from any suitable source. For example, it may be recovered by washing from the flue gas. A further source of carbon dioxide is the wet gas purification, particularly under pressure, of coal distillation gases.

## We claim:

1. In a process for the production of metalliferous coke adapted for blast furnace operation, the steps comprising; mixing predetermined quantities of coal, iron ore and a material selected from the group consisting of heavy mineral oil and tar oil, in amounts of from about 1-3% and applying heat to said mixture to effect coking thereof.
2. A process according to claim 1 wherein the material from the group consisting of heavy mineral oil, and tar oil, is first admixed with the ore and the resulting mixture then combined with the caking coal.
3. In a process for the production of metalliferous coke adapted for blast furnace operation, the steps comprising: mixing predetermined quantities of bituminous coal, iron ore of the type  $\text{Fe}_2\text{O}_3$  and a material selected from the group consisting of heavy mineral oil and tar oil, and applying heat to said mixture to effect coking thereof.

4. A process according to claim 1 wherein the iron ore used is of the type  $\text{Fe}_3\text{O}_4$ .
5. A process according to claim 1 wherein all of the iron ore has a grain size of less than 1 millimeter.
6. A process according to claim 1 wherein a caking coal is used and wherein about 80% by weight of the coal has a grain size below 2 millimeters.

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