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PROCESSING OF IRON OXIDE VALUES

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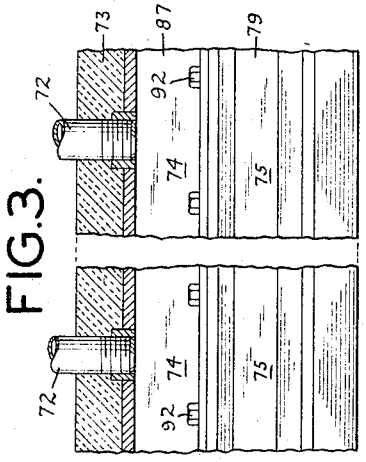


FIG. 3.

FIG. 1.

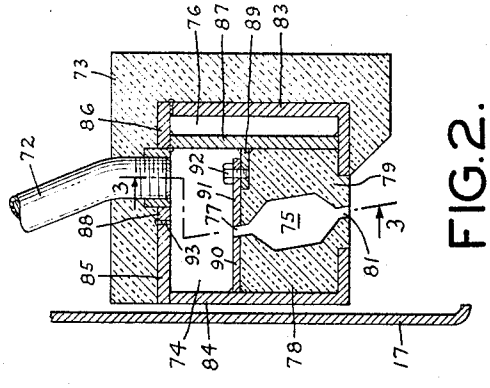


FIG. 2.

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PROCESSING OF IRON OXIDE VALUES

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Continuation-in-part of application Ser. No. 359,224, Apr. 13, 1964. This application Aug. 23, 1967, Ser. No. 667,025

9 Claims. (Cl. 75—4)

ABSTRACT OF THE DISCLOSURE

This invention relates to treatment of iron oxide values such as iron ores, and more particularly to production from such ores of hard, porous, high strength, shock-resistant preshaped materials containing the metal values and carbonaceous material as a new and improved feed for reduction furnace processing of the ore for conversion to the base metal, including blast furnace type operations for manufacture of iron, said preshaped products being obtained by subjecting to continuous coking conditions preformed green briquettes and the like composed of coal, finely divided iron oxide values, and hydrocarbon liquid such as fuel oil.

This application is a continuation-in-part of copending application Ser. No. 359,224, filed Apr. 13, 1964, now abandoned.

A number of oxidic ores can be treated by various reduction processes to produce the base metal. Iron, for example, is produced in the well-known blast furnace operation by reduction of iron oxide in the ore using carbon in the form of coke and oxygen supplied from ordinary air. In the conventional blast furnace operation the coke, ore and a slag-forming material are charged separately at the top of the furnace to form a series of individual and recurring layers. The charged materials descend in the furnace over the course of about 5–10 hours during which the iron oxide content of the ore is converted to iron or a molten complex thereof with carbon, commonly known as cementite (FeC).

Major cost factors involved in the production of iron in the conventional blast furnace include the tremendous capital investment in the installation and the extended processing time required to convert the ore. Moreover, the coke required for production of iron in the blast furnace must be of metallurgical grade. Coke of this quality is conventionally produced batchwise in the standard coke oven which is also a large installation requiring high capital investment and extended processing times of 16–35 hours. The resulting high price of the metallurgical cokes make them premium materials and also a major cost factor in the production of iron.

Clearly, there is room for reducing the cost of producing iron in blast furnace type operations and particularly in the areas of production rate and cost of raw materials such as coke. Several possibilities along these lines have been explored by the prior art workers. One approach is to combine the iron ore with the carbon required for the operation and thereby provide a combined feed material capable of being processed at higher rates in the furnace. Another more advanced and desirable approach is to provide a feed material containing the iron ore values and coke which has been produced from ordinary coking coal in admixture with the iron ore under coking conditions. In this manner the added expense of the usual coke oven operation could be eliminated while simultaneously providing a feed capable of conversion to iron at high rate in blast furnace type operations. However, the production of a feed material from ore and coal is not a simple matter and several factors including strength and quality of

the feed material have been major problems in this area. This is substantiated by the fact that the obvious economic potential of providing a combined feed material has attracted the efforts of many prior art workers yet no successful method for obtaining such a valuable material has been forthcoming.

An object of the present invention is to provide a new and improved method of processing oxidic ores.

Another object of the invention is to provide a new and improved feed material for oxidic ore reduction operations, such as a blast furnace.

Another object is to provide a practical and efficient method for producing a feed material containing oxidic ore values and carbon for production of the base metal in reduction furnace operations.

A further object is to provide a method for producing a feed material for oxidic ore reduction operations with the ore values combined with coke produced in admixture with the ore from ordinary coking coal.

A still further object is to provide a continuous process for producing at high rates a blast furnace feed material containing coke and iron ore values by coking of ordinary coking coal in admixture with iron ore.

Other objects and advantages will be evident from the following description of the invention and accompanying drawing.

It has been found in accordance with the invention that a combined feed material containing oxidic ore values and coke and suitable for reduction furnace operations such as a blast furnace may be produced and in a highly efficient manner by subjecting a moving mass of shaped bodies containing oxidic ore and coking-coal to hot combustion gases under coking conditions, said shaped bodies comprisnig (a) about 25–75 parts by weight coking-coal; (b) about 25–75 parts by weight of a finely divided material selected from the group consisting of oxidic ore and mixtures of oxidic ore with a slag-forming material; and (c) between about 3 to 40 parts by weight per 100 parts of said solids, preferably between about 4–15 parts per 100 parts solids, of a hydrocarbon liquid capable of slow and continuous gasification at the surface of the shaped bodies during coking, desirably a hydrocarbon oil the major portion of which is gasified from the shapes at a temperature between about 700 to 1100° F. The present invention features the continuous production at high rates of a highly reactive combined feed material containing ore values and coke for reduction furnace operations such as in a blast furnace for production of iron. The feed material may be prepared from the oxidic ore and ordinary coking-coal and, if desired, a portion of the ore in the shapes processed may be substituted by a slag-forming material such as limestone to provide a material in which all major reactants in the usual reduction operation are combined. Another particular feature of the invention is that finely divided ore is employed in makeup of the shapes enabling the utilization of certain ore forms such as those produced in the well-known Taconite Process, including the ore fines produced in that process and heretofore considered of marginal value.

The present invention will be further described in detail with reference to the accompanying drawing in which:

FIG. 1 is a combined sectional and diagrammatic view illustrating a preferred embodiment in which a blast furnace feed material is produced on a traveling grate which, as illustrated, may be a traveling grate stoker for conducting the process within a boiler setting.

FIG. 2 is a vertical section showing in a preferred form of an ignitor for igniting solids on the traveling grate.

FIG. 3 is a sectional view taken along line 3—3 of FIG.

2 showing in further detail the internal construction of the ignitor.

Referring to FIG. 1, a furnace **10** includes a coking chamber **11** within which is a conventional moving bed or traveling grate stoker **13** which moves left to right as shown on the drawing. The base wall **14** supports a hopper **16** which continuously deposits solid fuel on the upstream end of the traveling grate **13**. The total run of the grate from the upstream end to discharge at the downstream end is typically about 30 feet with the transverse width of the grate typically about 25 feet. The inner wall of hopper **16** is formed by furnace door or gate **17** which is movable vertically by a conventional screw mechanism **18** to control the thickness of the solid fuel which is disposed as a relatively thin bed or underlayer on the traveling grate. The particular solid fuel deposited on the grate from hopper **16** may be any solid carbonaceous fuel such as bituminous coal, steam coal, anthracite, subbituminous coal, lignite coal and coke breeze. In the more preferred forms of practice steam coal is employed as the solid fuel as it is a relatively inexpensive material which gives excellent results. The door **17** which is supported by wall **19** also combines with an adjustable gate **21** supported on main wall **22** to form a feed channel **24** from which the shapes **26** of ore and coking coal are deposited uniformly in controlled amounts on the underlayer of solid fuel. The amount of ore-coal material is regulated by gate **21** which is adjustable vertically by a conventional screw mechanism **27**. Before deposition of the coking material the underlying solid fuel is ignited by direct flame impingement by an ignitor **31** located behind the gate **17** and closely positioned over the moving bed of solid fuel. Ignition is facilitated by air from air-supply box **32** which together with air-supply boxes **33**, **34**, **35**, **36**, **37**, **38**, **39**, **40**, **41** and **42** provide sufficient oxygen from beneath the traveling grate to sustain combustion of the solid fuel throughout the grate run. The hot gases from combustion of the solid fuel rise upwardly through the ore-coal shapes to effect coking of the coal in the shapes with attendant release of volatile matter from the coke-forming material. Coking of the coal takes place progressively on the grate with the material discharged at the end of the grate run containing a high quality coke and ore values intimately associated in a hard, high strength shape suitable for metallurgical operations such as a blast furnace. The oxidic metal in the ore is partially reduced during the process such that preformed shapes prepared from iron ore readily attract and hold magnetized materials.

In carrying out the invention for the production of a reduction furnace feed the use of ore-coal shapes of definite composition is particularly important. A fundamental problem in producing an ore-coke feed resides in preventing decrepitation of the coal portion of the feed during coking which will weaken the shape to such an extent that its strength will not remotely approximate the requirements for metallurgical quality. It has been found that an important factor contributing to the successful production of the combined ore-coke feed material in the present invention resides in the provision of preformed bodies or shapes in which the oxidic ore and coking-coal are intimately admixed with a hydrocarbon liquid capable of gasification at the surface of the preformed shape under coking conditions. Briquettes, pellets and other formed shapes containing the indicated components have been found to convert under coking conditions to a product exhibiting not only surprisingly high strength and hardness but also a product in which ash content due to the coal is minimized. While no explanation can be given with certainty, the hydrocarbon liquid is a particularly important component which is believed to contribute to the formation of a satisfactory product for several reasons. Upon heating of the preformed shape the liquid hydrocarbon moves from the inner regions of the shape to the outer surface where it is gasified. This movement or wick-like flow of the cooler liquid into the hotter outer zones of the shape will exert a cooling action which significantly lessens the extreme thermal gradient which otherwise tends to be disruptive, causing decrepitation of the body. Similarly, heat is absorbed on gasification of the liquid at the surface of the shape and also effects a cooling action which prevents the shape from overheating and extreme high temperatures which weaken the product. Also, the gasification of the liquid tends to create a protective gas envelope surrounding the surface of the shape and serves to protect the fixed carbon from combustion as well as having an insulation effect. Thus, while the shapes are surrounded by hot gases creating intense and rapid heating conditions the actual heating rate of the shaped bodies, although rapid to the extent that high production rates are realized, nevertheless is controlled by the protective gasification of the liquid hydrocarbon at a rate below which the normally destructive and weakening forces come into play. The use of a hydrocarbon liquid which does not rapidly vaporize but slowly and continuously gasifies at the surface of the shape enables the production of a high strength material on a continuous basis even under the severe conditions encountered when the shapes are immersed in very hot gases and the operation is carried out simultaneously with a boiler operation. It is not essential that gasification of the liquid hydrocarbon take place over the entire course of the grate run or range of coking temperatures which usually exceed 1,500° F. Apparently, the gasification is most beneficial during a critical period commencing when the shapes are heated to a temperature of about 500° F. and ranging up to at emperature of 1,100° F. It is during this period that the "green" shapes undergo substantial change, particularly beginning with plasticization of the coal in the shapes at more or less about 700° F. (depending upon the coking-coal) and ranging up to a temperature of about 1,100° F. at which essentially all or at least a major part of the carbon structure has been formed. Hence, the hydrocarbon liquids employed in the invention should be such that at least about a major portion will gasify from the shaped bodies when the bodies are heated to a temperature above about 500° F., desirably such that at least about a major portion will gasify from the shapes at a temperature within the range of about 500–1,100° F., which range of temperatures shall be deemed included within the term coking conditions as used herein. Desirably, the liquid hydrocarbon is such that at least about a major portion will gasify as the shapes are heated within the temperature range between about 700–1,100° F. Hence, it is preferred that the operation on the continuous grate be conducted such that gasification continues at a good rate in the initial and intermediate zones with essentially all gasification from the shape completed well before the end of the grate run. To insure slow and continuous gasification at the surface of the shapes it is necessary to use hydrocarbon liquids which do not have a sharp boiling point but rather distill or gasify over a range of temperatures of at least about 200° F., preferably over a temperature range of at least 300° F. The preferred hydrocarbon liquids are the hydrocarbon oils and desirably those also having a total heat requirement to gasify about about 1,400 B.t.u./lb. preferably above about 1,600 B.t.u./lb. Included among the preferred materials are the petroleum derivatives having distillation ranges such that at least about 50% of the material is gasified at a temperature above about 500° F., preferably between about 500–1,100° F. The more preferred materials are the petroleum derived fuel oils having distillation ranges such that at least 50% of the fuel oil by weight is gasified at a temperature between about 700–1,100° F. Examples of the preferred petroleum oil fraction include residual fuel oils, Bunker C oil, No. 6 fuel oil, asphalt and blends of these or similar oils. Tar oils are also included among the preferred hydrocarbon liquids. Particularly excellent results are obtained when employing the petroleum derivatives

similar to or approximating the material commonly designated as No. 6 fuel oil, according to ASTM D396–48T.

The oxidic or oxide-bearing ore employed in make-up of the shaped bodies contributes to the strength of the product and must be finely divided. Particle size of the ore should be such that it is predominantly less than about 50 Tyler Standard Mesh, desirably about 70 percent minus 200 mesh. It is desirable but not absolutely essential that the ore be concentrated to remove silica to a level less than about 10%. In producing a feed for production of iron in a blast furnace particularly good results are obtained with ore fines such as those produced in the well-known Taconite Process. These materials generally contain about 55–59% by weight iron (total as Fe) in the form of iron oxides and have particle size approximating about 70% minus 200 mesh with 50% minus 325 mesh. A feed material for production of iron may also be produced from other suitable oxidic ores such as hematite, limonite, magnetite, and siderite. Typically these ores after concentration to less than 10% silica contain about 55–65% iron (total as Fe), about 5–10% water, about 3–8% silica, and about 1–3% lime and magnesia. If desired, a portion of the ore used in make-up of the shapes may be substituted by a slag-forming flux material to produce essentially a single feed material for a reduction furnace operation such as the blast furnace. The slag-forming material must be finely-divided with particle size requirements similar to those of the ore. Examples for suitable slag-forming materials which may be employed include limestone, rock dust, dolomite, fluorspar, hydrated lime, and soda ash. Proportions in which the ore and slag-forming material are used may vary over a fairly wide range depending largely on the amount of such material desired in the reduction furnace operation. With most ores a preferred formulation of the shapes includes the ore and slag-forming material in ratios of about 8:1 to 1:1, desirably within the range of about 6:1 to 3:1. Limestone is the preferred slag-forming material for a blast furnace feed for production of iron.

Preparation of the shapes from which the feed material of the invention is produced may be by any suitable method such as briquetting, pelletizing or other conventional procedure for producing aggregate or formed bodies. Generally, a satisfactory method of preparation involves intimately mixing the finely divided ore, coking coal, and hydrocarbon liquid after which the mixture is formed by the desired aggregating procedure into shapes of preselected size, shape and bulk. The preferred method found to give particularly good results involves briquetting of the mixed formulation which may be carried out in apparatus conventional for such purposes. Pressure employed in the briquetting are preferably of the order of about 2,000–5,000 p.s.i. to produce "green" briquettes having a porosity preferably between about 10–40%, more preferably between about 15–20%. The briquettes are preferably approximately cylindrical, spherical or cushion-shaped, with volume of the individual briquetted shapes giving good results for production of a blast furnace feed material between about 0.2–14 cubic inches, preferably within the range of about 0.3–5 cubic inches. The mixed formulation may also be pelletized into rounded shapes having a diameter of about ¾ to 3 inches, more preferably a size of about 1 to 2 inches in diameter. Pelletization may be accomplished in a conventional roll mill or other suitable pelletizing apparatus at about ambient temperatures with the resulting spherical shapes having a porosity within the range of about 15 to 20%. Special shapes may be prepared by related methods or other conventional techniques. Cylindrical or tubular shapes may be formed from the mixture from extrusion at a temperature preferably between about 190° F.–840° F. and pressures desirably in the range of about 30–1,000 p.s.i.

Proportions of the mixture used in preparing the shaped bodies will vary somewhat depending on several factors. Generally, at least about 3% by weight hydrocarbon liquid is required to produce a satisfactory feed material for metallurgical use. Amounts greater than about 40% are undesirable because of difficulty of producing workable mixtures and because of agglomeration during carbonization. The optimum amount of hydrocarbon liquid in any given case is determined largely by the performance of the liquid, size and degree of compaction of the shaped body, the coking rate and method of forming the shapes. Generally, the larger amounts of liquid are required when the size of the shape and coking rates are the greater and the density of the shape in the lower ranges. For example, larger shapes formed by pelletizing and to be processed at high coking rates are preferably formed employing the preferred petroleum fuel oils in amounts constituting about 15–40 parts by weight per 100 parts of the dry solids in the mixture, more usually about 20–30 parts. The preferred compacted briquette forms give particularly good results when the preferred fuel oil is added in the amount of about 3–15 parts, more desirably about 4–10 parts. In order to produce the satisfactory feed material at least about 25% by weight of the formulation mixture (dry basis) should be composed of finely divided ore or mixtures of ore and slag-forming materials. Amounts in excess of about 65–70% of finely divided ore tend to weaken the product such that amounts in excess of about 75% produce a material unsatisfactory for metallurgical use. Best results are obtained in producing a blast furnace feed material when the finely divided ore or mixture of ore and slag-forming material constitutes about 35–70% by dry weight of the formulation. The coking coals employed in the shapes may be any of the coals which form coke on release of volatile matter. It has been found that particularly excellent results are obtained in producing a feed material for reduction furnace operations with the higher volatile coking coals which are commonly distinguished by having a total oxygen content greater than about 7% by weight, usually in the range of about 8–10%, as determined by ultimate analysis under ASTM Test D271–58. Illinois coal is an example of such high volatile coals and the excellent results obtained therewith are surprising in view of known difficulty in obtaining quality high strength coke products therefrom. The amount of coal employed in the formulation generally may range from about 25–75% of the mixture (dry basis), preferably between about 30 to 65% depending on the particular coal employed. The so-called higher quality coking coals such as Eastern U.S. coals, and Australian coals are preferably employed in amounts between 30 to 55% by dry weight to give shaped products of excellent high strength and quality. As employed in the invention the coking coals are of controlled size preferably depending largely on the coking value of the coal and amount in the formulation. The more weakly coking coals such as Illinois coal with which good results are obtained by the invention are preferably employed in the higher amounts between about 35–65% and preferably have size of about 0 to ¼", more preferably 0 to ⅛", in accordance with the customary designations employed in the art. The higher quality coking coals which are preferably employed in lesser amounts aforesaid are preferably somewhat more finely divided to predominantly pass a 20 Tyler Standard screen, more preferably of size such that about 100% passes a 40 Standard screen.

The following exemplary formulations are merely illustrative of the invention.

FORMULATION I

	Parts
Illinois coal 100% minus 3 mesh	55
Taconite fines 70% minus 200 mesh	45
No. 6 fuel oil	7

When briquetted on a laboratory Carver Press and sub-

jected to coking conditions in accordance with the invention the resulting iron-coke products are hard, highly porous, exceptionally shock-resistant bodies each having a continuous coke phase, a high compressive strength, and an apparent specific gravity of about 1.6.

FORMULATION II

	Parts
W. Virginia (Tralee) high volatile medium oxygen coal 95% minus 60 mesh	35
Erie iron ore 90% minus 200 mesh	65
No. 6 fuel oil	7

When briquetted on a commercial scale briquetting machine of the roll type at a hydraulic roll pressure of about 1,700 pounds (3 briquettes in each row) and subjected to coking in accordance with the invention, the resulting iron-coke products are hard, porous, shock-resistant bodies each having a continuous coke phase, a compressive strength of about 3100–3300, a porosity of between about 45–55%, and an apparent specific gravity of about 1.5.

FORMULATION III

	Parts
W. Virginia (Tralee) high volatile medium oxygen coal 85% minus 40 mesh	31
Erie iron ore 90% minus 200 mesh	69
No. 6 fuel oil	7

When briquetted and coked the same as Formulation II the resulting iron-coke products are hard, porous, shock resistant bodies each having a continuous coke phase, a compressive strength of about 2800–3000 p.s.i., a porosity of between 45–50%, and apparatus specific gravity of about 1.5.

Again with reference to FIG. 1, the amount of solid fuel deposited on the grate **13** from hopper **16** is determined by the requirement of providing sufficient hot combustion gases to effect substantial coking of the coal in the shapes deposited on the fuel from feed channel **24**. The upper layer of shaped bodies is relatively thin or less than about 24 inches to avoid destructive pressures and undesirable agglomeration. Thickness of the upper layer is preferably about 8–12 inches while thickness of the underlying fuel layer is correspondingly about 3–6 inches. The amount of undergrate air from air-supply boxes **32–42**, inclusive, is regulated to supply sufficient hot combustion gases for coking of the shapes and, if desired, also for the simultaneous generation of steam in the boiler setting. The combustion gases entering the mass of shaped bodies have a temperature greater than 1,500° F. up to about 3,000° F., preferably between about 2,000° F. to 2,600° F. Desirably, the total amount of air and solid fuel are controlled such that the solid fuel is finally consumed as the grate reaches the end of the run with ash from the fuel along with the preformed shapes discharged into a suitable bin (not shown). The coked shapes discharged from the grate may still contain volatile matter which is driven off by holding the hot shapes in the product receptacle for a short time prior to quenching and screening.

The volatiles expelled from the shapes on the traveling grate are carried upwardly by the rising hot combustion gases and, if desired, may be consumed to supply heat for generation of steam in boiler setting **60**. For this purpose, secondary air is introduced through ports **61–65** in the side walls of the coking chamber and through a series of spaced ports **66** and **67** located traversely of the grate. The secondary air is provided to effect combustion of the uprising gases which creates a fireball in the boiler setting area **60** and supplies heat for generation of steam in the boiler setting which includes the transverse series of boiler tubes **68** and **69**. If desired, volatiles released from the shapes after discharge from the end of the grate may also be led to the boiler setting area and consumed to supply heat. In the better forms of practice the amount of air supplied from the air-supply boxes **32–42** is varied according to the amount of combustion of the solid fuel to take place on the corresponding grate section. The amount of air is controlled to avoid overheating or the possibility that any substantial amounts of oxygen pass through the solid fuel bed to the shapes. The amount of air supplied and combustion of the solid fuel may be varied to control the rate of coking or carbonization of the coking coal in the shapes. Progressive coking at rapid but non-excessive rates is usually accomplished when combustion of the solid fuel is greatest, near or just past the intermediate sections of the grate. Hence, the greater amounts of air are desirably supplied in these sections with lesser amounts at the upstream and downstream ends of the grate run. For complete combustion of the solid fuel the actual amount of undergrate air supplied is usually equivalent to an average rate of about 200 to 600 lbs. per square foot of grate area per hour during the grate run. In the more preferred embodiments involving production of feed material for production of iron and generation of steam in a conventional boiler setting the average amount of air is desirably about 400 to 550 lbs. per square foot of grate area per hour. The grate is preferably advanced at a rate of about 0.5–4 feet per minute, and desirably at a rate of about 1–2 feet per minute.

Direct and uniform ignition of the upper portion of the bed of solid fuel deposited on the traveling grate from hopper **16** has been found important in obtaining good results, particularly when the operation is carried out to supply heat for generation of steam in a boiler setting. As shown in FIG. 1, positive and uniform ignition of the solid fuel is desirably accomplished by an ignitor **31** located behind the gate **17** and positioned closely above the top of the moving bed of fuel disposed on the grate from hopper **16**. Ignitor **31** extends transversely across substantially the entire width of the moving fuel bed and operates to impinge a direct high velocity flame onto the moving bed to the extent that a broad flame penetrates about 0.5–1 inch or about 10–25% of the bed thickness. Breadth of the flame at the point of contact is desirably about 2–4 inches such that the flame impinges on the solid fuel for sufficient time to ignite it thoroughly. In operation, ignitor **31** receives a fuel gas-air mixture from a manifold **71** through a series of supply lines **72** spaced along the length of the ignitor. A number of suitable gaseous fuels may be employed in ignition including the natural hydrocarbon gases such as methane, ethane, etc., and the manufactured fuels such as water gas or producer gas. Preferably, the fuel gas is natural gas, containing about 90% methane, 5% ethane and 5% nitrogen. Air containing about 21% oxygen is fed along with the fuel introduced into the ignitor, the amount of air being regulated to furnish just enough oxygen to completely burn the natural gas. An ignitor assembly is shown in detail in FIGS. 2 and 3. This assembly includes generally an outer housing **73** of a suitable heat-insulating material such as magnesia, a combustible mixture channel **74**, combustion chamber **75** and cooling zone **76**. The fuel-air mixture introduced through lines **72** into channel **74** is lead under a pressure of preferably about 0.5–1.5 p.s.i. through an elongated narrow passageway **77** into the enlarged combustion chamber or zone **75** formed by walls **78** and **79** which are also constructed of a heat-insulating material. The fuel gases ignited in chamber **75** are discharged therefrom as a high velocity jet flame through the converging outlet **81** which may be a straight elongated type outlet or converging to a narrow passageway, substantially as shown in FIG. 3. Coolant circulated through cooling zone **76** serves to prevent overheating of the ignitor assembly generally and avoid preignition of the fuel in the mixture channel **74**. Suitable cooling substances include air, steam, water and natural gas, preferably air. The main body of ignitor **31** may be constructed of suitable strength and heat resistant material. Steel members welded together are satisfactory

and the ignitor may be so constructed from L-shape members **83** and **84** and plate members **85, 86, 87, 88, 89, 90** and **91**. Plate **91** is secured to plate **89** by threaded bolts **92** to permit adjustment of the width of gas channel **77**. Thus, the ignitor may be constructed in half sections to facilitate placement of refractories **78** and **79** and finally joined by a weld **93** on installation. The ignitor **31** is adjustably suspended typically 8–12 inches from the solid fuel bed by the supply lines **72** which are typically 4–6 in number along a bed of approximately 25 foot width.

The present invention provides generally for the manufacture of a combined feed material containing ore values and coke for production of the base metal in reduction furnace operations. Particularly advantageous is the fact that such materials may be produced at exceptionally fast rates with residence time on the traveling grate being only about 10–60 minutes, more usually about 20–45 minutes. The combined products produced by the invention containing iron ore values and coke represent a superior feed for use in a blast furnace to produce iron at high rates and in a highly efficient manner. The products produced by the invention for blast furnace use are hard, porous, shock resistant, materials comprising a continuous coke phase having dispersed therein iron ore values partially reduced to the extent that the shapes are capable of holding magnetized metals. The continuous phase of the products can be determined by microphotoanalysis of a cross-section of shaped bodies, for example, at a 40 times magnification. The presence of the continuous coke phase contributes substantially to the strength of the products and ability to be used in blast or other high shaft reduction furnaces by retaining strength in the coke portion or skeleton of the body after reduction or flow of iron values from the shape. Thus, load supporting capability of the shape even after substantial reduction is retained as necessary in reduction furnace operation. Size of the shapes will range from about 0.3 to 8.0 cubic inches, preferably about 0.5 to 4.0 cubic inches. The product shapes have characteristic porosity which may range between at least about 10% up to 60% by volume, more usually 30–55% by volume as may be determined in water acording to well known Standard ASTM tests. The shaped products have exceptionaly high compressive strength of at least 300 p.s.i., usually in excess of 500 p.s.i. There can be produced by the invention shaped products having compressive strengths of at least 2200 p.s.i., and those of compressive strengths of at least 2600 p.s.i. as determined on specimens cut from the individual shaped bodies and having two opposing parallel surfaces suitable for accurate testing in standard strength testing apparatus. Thus, there can be produced by the invention products having compressive strengths approaching and approximating that of homogeneous coked bodies of the coal employed as produced, for example, in a conventional coke oven. Strength performance in terms of resistance to breakage on tumbling or dropping can even exceed that of coke from conventional coking processes for certain coals such as the weakly coking Illinois coals in the sense that such coals have been heretofore difficult to produce with strengths sufficient to resist breakage or break down during processing and handling to size impractical for blast furnace use. The exceptional strength of the iron-coke products of the invention reflects in large part the presence of the continuous coke phase thereof which in turn is largely responsible to the retention of high supporting strength of the products even after substantial reduction of the iron oxides values therein as in a conventional blast furnace. The shapes also have an apparent specific gravity between about 1.2 to 2.0, more usually between about 1.4 to 1.8. The coke formed within the shapes is high quality material of metallurgical strength and form stability with desirable low coal ash content less than about 10%, more usually less than about 9%. Other oxidic ores which may be processed by the present invention with similar results to provide a feed material for production of one or more base metals include the chromite ores for production of chromium or ferrochrome, nickel bearing ores for production of ferroalloys, manganese bearing ores for production ferromanganese, and silica for production of ferrosilicon. The oxidic ores also may be substituted in whole or in part by finely divided iron oxide dust obtained from basic oxygen furnaces currently employed by the steel industry. Such dust, largely in the form of Fe_2O_3, can be employed when meeting the fine size requirements herein specified for the iron ore and yields hard, porous, shock-resistant bodies substantially similar to the shaped products obtained with iron ore. Phophates ores can also be used in the shapes to produce ultimately phosphorus or phosphorus pentoxide.

Although certain preferred embodiments of the invention have been disclosed for purpose of illustration, it will be evident that various changes and modifications may be made therein without departing from the scope and spirit of the invention.

I claim:

1. A continuous process for the production of a metallurgical grade material containing iron values and coke which comprises: (A) disposing a layer of solid fuel on a continuously moving permeable bed; (B) igniting said solid fuel; (C) disposing on said first layer a second layer of shaped bodies prepared by aggregating an intimate mixture composed of (a) about 25–75 parts by weight coking coal; (b) about 25–75 parts by weight of a finely divided material selected from the group consisting of iron oxides and mixtures of iron oxides with slag-forming material; in ratio between about 8:1 to 1:1, said iron oxide having particle size such that at least the major portion is les than 50 Tyler Standard Mesh in size; and (c) between about 3 to 40 parts by weight per 100 parts of said solids of a hydrocarbon liquid capable of continuous gasification at the surface of the shaped bodies during coking; and (D) subjecting said second layer of shaped bodies to uprising hot gases from combustion of said first layer of solid fuel for time sufficient to coke the coal in said shaped bodies.

2. The process of claim **1** in which the hydrocarbon liquid in the shaped bodies is such that a major portion of such liquid is gasified on heating to temperatures from between about 500 to 1,100° F.

3. The process of claim **1** in which the coking coal is a high volatile coal characterized by having an oxygen content of at least about 7% as determined by ultimate analysis under ASTM Test D271–58.

4. The process of claim **1** in which the iron oxide is iron ore.

5. The process of claim **4** in which the hydrocarbon liquid is No. 6 fuel oil.

6. The continuous process for production of a metallurgical grade material containing iron ore values and coke which comprises: (A) disposing a layer of solid fuel on a continuously moving permeable bed; (B) impinging a flame directly on the upper portion of said layer of solid fuel to effect positive and uniform ignition of said fuel; (C) disposing on said ignited fuel a second layer of shaped bodies prepared by briquetting an intimate mixture composed of (a) about 30–65 parts by weight coking coal; (b) about 35–70 parts by weight of a finely divided material selected from the group consisting of iron ore and mixtures of iron ore with a slag-forming material in ratio between about 8:1 to 1:1; said iron ore having particle size such that at least about 70% is minus 200 Tyler Standard Mesh; and (c) about 4–15 parts by weight per 100 parts of said solids of No. 6 petroleum fuel; (D) feeding an oxygen-containing gas upwardly into said first layer of solid fuel to maintain combustion thereof and cause combustion gases at temperatures within the range of about 1,500–3,000° F. to

pass through said second layer of shaped bodies; and (E) subjecting said shaped bodies to said hot combustion gases to progressively heat and coke the coal in the shapes to form hard, shock-resistant preformed bodies composed of a continuous coke phase containing iron ore values.

7. A metallurgical grade feed material for reduction furnace operations comprising a hard, porous, shock resistant, preformed body having a continuous coke phase with iron oxide values dispersed throughout, said body having a compressive strength of at least 500 p.s.i., a porosity between about 15% to 60% by volume, and an apparent specific gravity between 1.2 to 2.0.

8. A metallurgical grade feed material for reduction furnace operations comprising a hard, porous, shock resistant, preformed body having a continuous coke phase with iron ore values dispersed throughout, said body having a compressive strength of at least 2200 p.s.i., a porosity between about 15% to 60% by volume, and an apparent specific gravity between 1.2 to 2.0.

9. A metallurgical grade feed material for reduction furnace operations comprising a hard, porous, shock resistant preformed body having a continuous coke phase with iron ore values dispersed throughout and partially reduced to the extent that the shape is capable of holding magnetized metal, said body having compressive strength of at least 2600 p.s.i., a porosity between about 30% to 55% by volume, and an apparent specific gravity between 1.4 to 1.8.

No references cited.

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