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PRODUCTION OF IRON IN A BLAST FURNACE

Filed Jan. 21, 1950

2 Sheets-Sheet 1

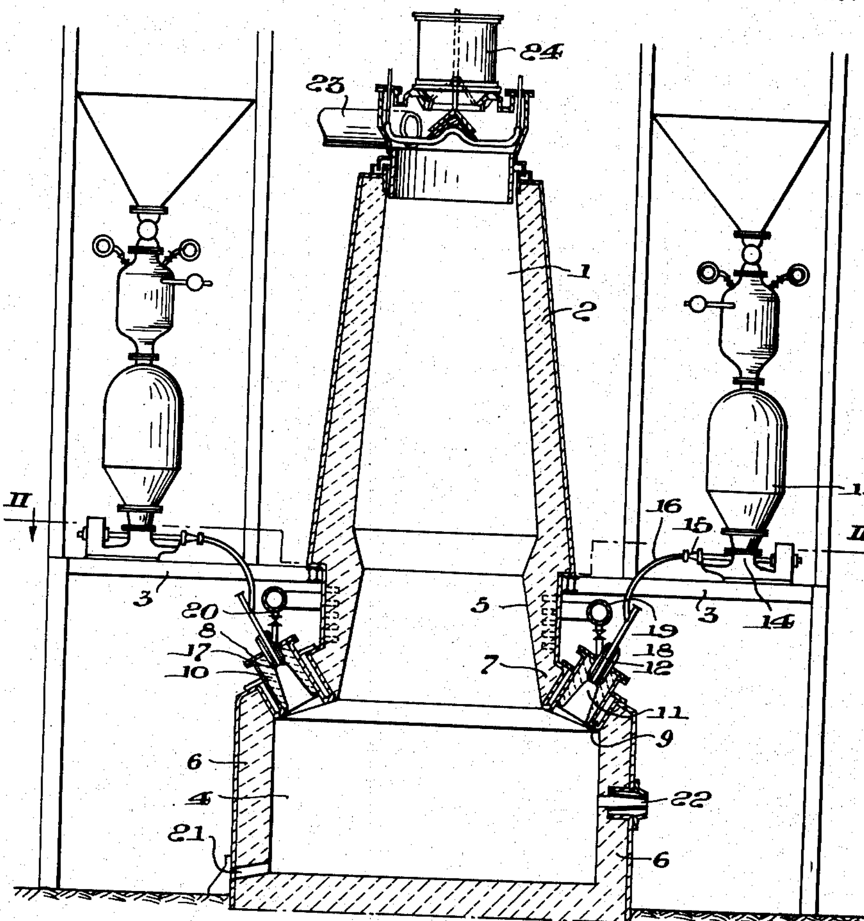

Fig. 1.

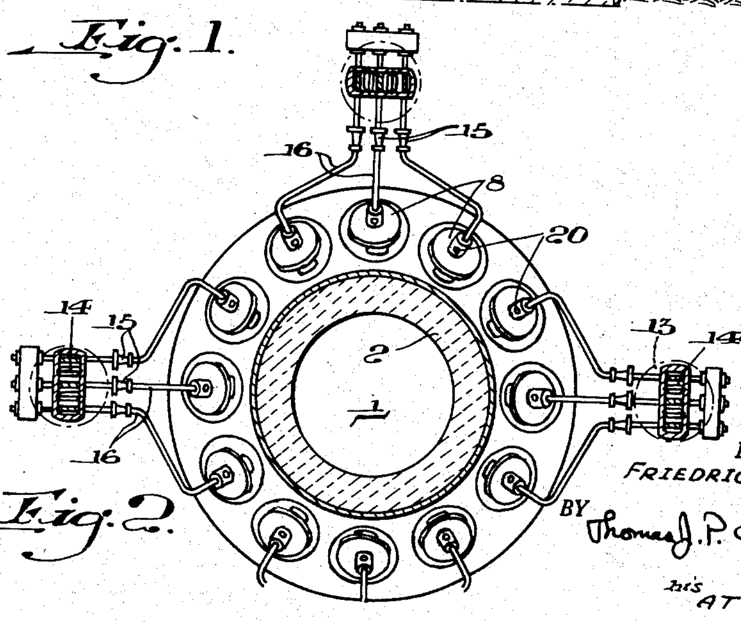

Fig. 2.

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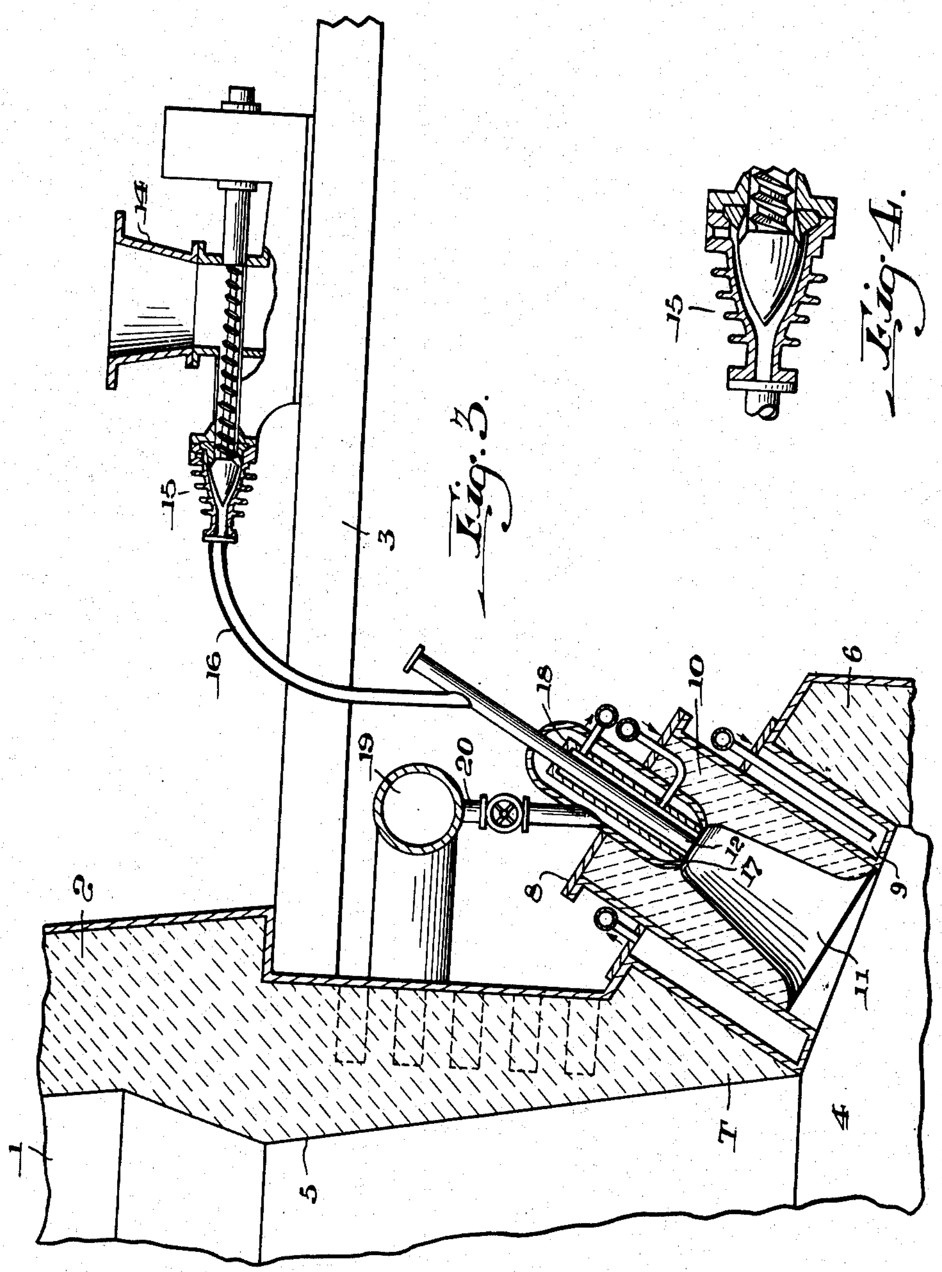

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PRODUCTION OF IRON IN A BLAST FURNACE

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6 Claims. (Cl. 75—41)

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The present invention relates in general to the production of molten iron in a blast furnace and, more specifically, to the production of molten iron in a blast furnace into which the employed solid fuel is introduced partly in the form of lumps and partly in a finely-divided state.

In the following description, the word "iron" is employed to include both pig iron and ferrous alloys.

Very early in the development of the blast-furnace art it was attempted to meet the requirements of a blast furnace as to its demands for solid fuel by charging a part of the fuel in a lumpy state along with the ore and the fluxing compounds at the top of the blast furnace and to supply the remainder by introducing pulverized, solid fuel into the hearth of the blast furnace along with the blast. The purpose of these earlier attempts was to reduce the required amount of expensive lump fuel by its partial substitution with finely-divided fuels. But all these earlier attempts did not meet with any success; it was found that with the employed methods of operation the required reactions in the hearth of the blast furnace are disturbed by blowing-in the pulverized fuel in the form of dust and that the amount of lump fuel was not decreased but rather that it was even increased when coal dust or the like was blown into the blast-furnace hearth. It was found that the coal dust in the hearth hardly reacted at all with the blast. Only heat was removed from the hearth by the introduction of the coal dust which had to be compensated for by an increased consumption of the lump fuel in the hearth.

In order to avoid these difficulties it has been proposed to preheat the finely-divided fuel before its introduction into the hearth in an externally heated pipe without admission of air. But also this method did not lead to success.

An object of the present invention is to provide improvements which, without disturbing the normal reactions in the blast furnace, permit the replacement of a considerable part of the required lump solid fuel by a finely-divided solid fuel.

Another object of the present invention is the production of iron in a blast furnace by means of lump solid fuel and to produce at the same time a blast-furnace gas which is suitable for carrying out chemical reactions; e. g., the synthesis of hydrocarbons or for other purposes.

Another object of the present invention is to produce iron in a blast furnace with the consumption of only relatively small amounts of lump fuel having a comparatively low crushing strength.

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Another object of the present invention is to provide such improvements in the construction of a blast furnace as permit the introduction of large amounts of finely-divided fuels into the hearth thereof.

Solid fuel as employed in the blast furnace serves four different functions, namely:

(1) The solid fuel provides the amount of carbon which reacts with the reduced iron in order to produce molten pig iron of the usual quality.

(2) The solid fuel provides the carbon required in the hearth of the blast furnace to effect the so-called direct reduction which is understood to be the reaction of the oxygen contained in the iron ore with the solid carbon probably according to the following equation: $C+FeO=CO+Fe$.

(3) Combustion of the solid fuel must also provide that amount of heat which is required for preparing and preheating the charge of iron ore, fluxing agents and the fuel itself up to the reaction temperature and for effecting the endothermical reactions and for melting down the slag and the metallic iron.

(4) In the lower parts of the blast furnace the solid fuel must also form a sort of grate on which the furnace-charge rests and which is permeable for gases and through which the gaseous media (blast) which take part in the reaction can be blown into the furnace and it finally must also make the total furnace-charge sufficiently permeable for the blast-furnace gas leaving the top of the furnace.

Of the above-mentioned four functions of solid fuel in the blast-furnace substantially only one can be filled by pulverized fuel; that is, the supplying of the required heat.

It is not possible to replace the lump fuel necessary for the direct reduction in the hearth of the blast furnace nor that amount of carbon which reacts with the metallic iron itself.

The amount of carbon required for these purposes is estimated to be about 15%–20% of the total amount of fuel required for the usual operation of a blast furnace and it can be assumed that a modern blast furnace of common design and method of operation requires about 800–1000 kg. of coke per ton of pig iron produced, depending upon the characteristics of the ore.

The amount of lump fuel that is required for the formation of the gas-permeable grate and for securing a sufficient permeability of the furnace-charge depends of course on the properties of the ore and on the design of the blast furnace. Under optimum conditions it is possible that the amount of lump fuel required for the direct reduction and for the reaction with the molten iron is sufficient to secure the necessary permeability of the charge in the hearth and in the stack of the blast furnace.

From the aforesaid it follows that any important replacement of the lump fuel by coal dust, or the like, can be only effected when considerable amounts of the finely-divided fuel are introduced into the hearth itself. It is not generally possible to state the amount of coal dust that can be introduced into the hearth but when one considers that it is necessary to introduce at least 600–800 kg. of coal, or coke dust, per ton of pig iron into the hearth of the blast furnace in order to obtain a proper operation with the smallest possible consumption of lump fuel, it follows that the hereinbefore mentioned earlier proposals could not lead to an effective improvement.

The present invention comprises introducing into the tuyeres of a blast furnace a mixture of oxygen and finely-divided solid fuel which is as homogeneous as possible and which has been preformed at a relatively low temperature, said mixture being introduced into the tuyeres in such a way and under such conditions that the reaction between oxygen and the finely-divided solid fuel yields substantially only carbon monoxide and that this reaction is started at the outlet of the tuyeres and is completed before the reaction mixture comes into contact with the solid or fluid and/or pasty charge of the hearth.

In this description and in the following claims the term oxygen is understood to comprise pure oxygen or air with a highly increased content of oxygen, preferably a gas (air) with a content of more than 60% of oxygen.

The amount of oxygen which according to the present invention is to be introduced into the hearth along with the finely-divided solid fuel depends on several factors. In no case can the amount of oxygen be so great that stoichiometrically only carbon dioxide is formed by the reaction between the pulverized solid fuel and oxygen when the amount of hydrogen and hydrocarbons in the fuel are also taken into consideration in the calculation. On the other hand, in general, at least so much oxygen must be introduced that the finely-divided fuel which is to be added is utilized and converted into carbon monoxide and hydrogen. From a practical point of view the most advantageous method of operation is to produce a reaction gas that consists of carbon monoxide containing a fixed amount of carbon dioxide and hydrogen and/or steam. When calculating the amount of carbon dioxide which may be permissible it must be remembered that, because of the temperature prevailing in the hearth, the carbon dioxide will react with the lump fuel in the hearth and the consumption of lump fuel is thereby increased. In practical operation, moreover, a definite amount of carbon dioxide can be required in order to use up sufficient of the solid lump fuel in the hearth that the charge of the blast furnace descends in the necessary manner and this is especially so if the consumption of the lump fuel for the direct reduction and for the carbon used for the reaction with the metallic iron is inadequate to permit the charge to descend properly.

The concentration of oxygen in the gas (air) containing oxygen which along with the finely-divided fuel is introduced into the hearth of the furnace depends on the properties of the ore to

be used and on the properties desired in the pig iron to be produced.

If the ore is difficult to reduce the concentration of oxygen must be higher because the temperature in the hearth must be higher. Similarly the concentration of oxygen is to be increased if a pig iron of a higher melting point or a ferro-alloy is to be produced; such a case may for instance exist if a pig iron with a higher content of silicon is to be produced, while for the production of an open-hearth pig iron a lower temperature in the hearth is to be preferred in order to produce as little silicon as possible by reduction of the slag.

If the operation of a blast furnace is carried out according to the present invention it is possible to reduce considerably the consumption of lump solid fuel in the blast furnace but it must be remarked that the total requirement of finely-divided fuel for the blast furnace can be higher than in the case when the same blast furnace is operated only with lump solid fuel. But this additional consumption of solid fuel which may happen under certain circumstances, with the process according to this invention, affects only the amount of finely-divided fuel, the price of which usually is only a fraction of that for a lump fuel having a high crushing strength. It must also be considered that with the process according to the invention a valuable blast-furnace gas is produced which without further treatment can be used for the synthesis of valuable hydrocarbons, or for other purposes. With the process according to this invention the whole amount of the produced blast-furnace gas is available for use because of the use of oxygen and the preheating of the blast which otherwise is necessary can be omitted; as is well known the preheating of the blast in the normal operation of blast furnaces takes about one-third of the blast-furnace gas produced.

In this description and in the following claims the term lump solid fuel is understood to comprise such fuels as occur in pieces large enough to provide adequate permeability of the charge of ore, fluxing agents and fuel, in the furnace-stack and in the hearth of the blast furnace, and which also has sufficient crushing strength. In general, there can be considered, for example, coke from bituminous coal, charcoal, anthracite and other non-coking coals.

Practically any chosen solid fuel can be used as the finely-divided fuel if it has the necessary small size of grain. Preferably the invention uses a finely-divided solid fuel which leaves not more than 10% residue on a 4900 mesh sieve. It is unimportant whether the finely-divided solid fuel is of the coking or non-coking variety.

The ratio of the reactivity of the finely-divided solid fuel to that of the lump solid fuel is of no significance when applying this invention. Into a blast furnace which is operated for instance with an easily reactive charcoal as the lump fuel, there can be charged a finely-divided fuel of poor reactivity, for instance pulverized bituminous coal. Such utilization of poorly and easily reactive fuels simultaneously has before the present invention not been possible in the operation of a blast furnace.

The present invention also provides a novel design of the blast furnace to be used for the production of molten iron.

According to an essential feature of the present invention one or more so-called gasifying heads are provided in the walls of the hearth of the blast furnace, preferably such a number of gasifying heads that one or several continuous rows of gasifying heads are formed along the whole circumference of the hearth.

The single gasifying head is designed almost like a common water cooled tuyère or nozzle which usually serves to introduce the blast into the hearth of the blast furnace. But towards the inner part of the hearth the gasifying head is enlarged as compared with the common tuyère or nozzle so that an essentially conical space is formed which opens into the hearth with its wider end.

The homogeneous mixture of oxygen and finely-divided fuel which has been preformed outside the furnace is introduced at the narrowest point of this conical space and axially thereof in the form of a jet.

Advantageously the gasifying head is provided with water-cooled walls. Preferably, according to the invention, it is provided with a refractory lining in order to prevent losses of heat. Also the water-cooled walls can, according to the invention, be provided with a refractory lining.

The size and arrangement of the gasifying heads is so chosen that the conical space of the gasifying heads cannot be filled-in by the charge in the hearth during operation of the blast furnace. In this manner, according to the invention, a row of gasifying niches or chambers is formed each being sufficiently large that the reaction between oxygen and solid finely-divided fuel can practically be finished before the products of this reaction meet the solid or pasty charge in the hearth.

A preferred embodiment of the invention is to provide the hearth of the blast furnace with a greater diameter than the stack and to arrange the gasifying heads in the arch-like space between the stack and hearth. This design is shown on the attached drawing.

According to the invention it is also possible to line the gasifying heads with carbon bricks. In order to counteract attack of the carbon bricks by oxidation the invention provides that a reducing medium, preferably carbon monoxide, is introduced through an annular nozzle which is arranged at the narrower end of the gasifying head and co-axially around the inlet of the fuel-oxygen mixture and in such a way that a coherent film or envelope of carbon monoxide is formed on the surface of the carbon lining which envelope surrounds the jet of fuel and oxygen and flows along in surrounding relation therewith as the mixture reacts to form the carbon monoxide, thereby preventing the oxidizing medium from touching the surface of the carbon bricks.

Other important objects and features of the invention follow from the description of an advantageously used design of a blast furnace according to the present invention which is shown on the drawings: a vertical section in Figure 1 and in Figure 2 a horizontal section along line II—II of Figure 1, and in Figure 3, a sectional view showing the structure from the mixing device 15 to the water jacket 9 in greater detail.

Figure 4 is an enlarged view of the mixing device 15.

The blast furnace shown on the drawing comprises a stack 1 which tapers from the top downwardly and which is formed of refractory brickwork 2. The brickwork 2 is supported on a frame 3.

The lower end of the stack 1 opens into a tapered portion 5, the smallest diameter being adjacent the stack, as shown in Figure 1.

The hearth 4 formed by refractory walls 6 is of greater diameter than the tapered portion 5. In the arch-like wall 7 between stack and hearth a continuous row of gasifier heads 8 is arranged as can be seen from Figure 2.

As shown in Figure 1, the gasifier heads 8 comprise each a water-cooled jacketed body 9 provided with a refractory lining 10. The refractory lining 10 forms a reaction space 11 which is essentially conical and which opens with its enlarged end into the hearth 4. At the narrower end of the reaction space 11 there is a water-cooled nozzle or tuyère 12 adapted to introduce a mixture of finely-divided solid fuel and oxygen in the form of a jet into said reaction space.

The mixture of finely-divided solid fuel and oxygen are introduced into the nozzle 12 at a temperature and velocity such that the reaction between oxygen and carbon can start only inside the conical reaction space when the mixture has left the nozzle 12. This is determined empirically in the conventional manner for the purpose as is common practice in the art of thermodynamics.

From the storage bin 13 the finely-divided solid fuel passes into a transporting worm 14 through which it is conveyed continuously into a mixing device 15. In this mixing device 15 oxygen is introduced through a pipe, not shown on the drawing, in such a way that a mixture as homogeneous as possible of oxygen and finely-divided solid fuel is prepared. As the pressure of the oxygen is higher than the pressure in the hearth 4 the mixture flows from a said device 15 through a pipe 16 to an individual nozzle 12 connected therewith.

As shown in Figure 2, an individual mixing device 15 is provided for each gasifier head and/or each nozzle 12 and preferably also a conveying means 14 individual thereto is provided.

In the gasifier heads the nozzle 12 is surrounded by an annular orifice 17 which forms the end of the space 18. From the delivery main 19, carbon monoxide, for example, part of the produced blast-furnace gas can be introduced through pipe 20 into this space 18. The annular orifice 17 is preferably so arranged that the gas leaving through the annular orifice 17 is forced to flow along the walls of the conical reaction chamber 11.

The molten pig iron produced in the blast furnace is tapped off at 21 and the molten slag at 22.

The blast furnace shown in the drawing is of the so-called low-shaft type, the stack 1 being of relatively low height opens into the hearth without a so-called bosh. In spite of the decreased height of the stack the rate of the indirect reduction and consequently the specific consumption of fuel is as favourable as with the normal blast furnace, because the higher concentration of carbon monoxide in the gases accelerates the reduction. On the other hand it is possible and may be economical in certain circumstances to decrease the indirect reduction by further reducing the height of the stack so that the blast furnace gas contains little carbon dioxide. In such case the specific consumption of fuel per ton of iron produced is increased but the higher costs for the fuel are compensated by the higher value of the blast-furnace gas drawn off at 23. The possibility of also using a lump fuel of relatively low crushing strength is an important advantage of the low-shaft blast furnace.

The solid lump fuel, the ore and the fluxing materials are introduced through the throat of the blast furnace in the usual manner.

The invention as hereinabove set forth is embodied in particular form and manner but may be variously embodied within the scope of the claims hereinafter made.

I claim:

1. An improved process for producing metallic iron, from iron ore in a blast furnace by the introduction of pulverized solid fuel at the hearth of said blast furnace containing said ore, said process comprising: introducing the furnace charge of iron ore and flux along with lump solid carbonaceous fuel for direct reduction, for reaction with the metallic iron itself, and for gaseous permeability of the charge, into the blast furnace through the throat of the furnace; introducing the solid fuel for supplying the heat for the process by preforming outside the blast furnace hearth and at relatively low temperature a fluidized mixture of gas comprising more than 60 per cent, free oxygen and pulverized solid fuel with the oxygen in amount such as to yield by reaction with the solid fuel substantially only carbon monoxide but in amount such that the pulverized fuel of the mixture is substantially all utilized in conversion to carbon monoxide, flowing said mixture axially in the form of a jet into tuyères that communicate with the hearth of said blast furnace and initially igniting the mixture at the inlet of the tuyères and completing the thermal reaction to carbon monoxide of the reactants of said mixture in the tuyères in advance of emission from the tuyères into the hearth protecting the walls of the tuyères by surrounding the axial jet of the thermal reaction mixture, during its flow through the tuyères, with a surrounding flow of a gaseous reducing medium in direct contact therewith in the form of a reducing medium while the thermal reaction mixture is issuing into the tuyère path and flows through the tuyère path to the hearth; thereafter bringing the resultant thermal reaction mixture into contact with the iron ore at said blast furnace hearth, and passing the gases thereof upwardly through the furnace shaft through the furnace charge of iron ore, flux, and carbon introduced therewith as aforesaid through the throat of the furnace; and withdrawing the so-produced blast gas from the upper part of the furnace shaft.

2. A method as claimed in claim 1, and in which the tuyère path is of gradually increasing cross-sectional area in the direction of the hearth for effecting substantial completion of the thermal reaction of the reaction mixture therein before the mixture issues into the hearth charge from the tuyère path, and in which the surrounding flow of another cooling medium is carbon monoxide.

3. An improved process for producing metallic iron from iron ore in a blast furnace by introduction of pulverized solid fuel at the hearth of said blast furnace containing said ore, said process comprising: introducing the furnace charge of iron ore and flux along with lump solid carbonaceous fuel for direct reduction, for reaction with the metallic iron itself, and for gaseous permeability of the charge, into the blast furnace through the throat of the furnace; introducing the solid fuel for supplying the heat for the process by preforming outside the blast furnace hearth and at a relatively low temperature a fluidized mixture of a gas comprising more than 60 per cent free oxygen and pulverized solid fuel with the oxygen in amount insufficient to oxidize the carbon of said fuel to mainly carbon dioxide but in amount such that the pulverized solid fuel of the mixture is all utilized in conversion to gas by the oxygen of the mixture; flowing said mixture axially in the form of a jet through tuyères that communicate with the hearth of said blast furnace and initially igniting at the inlet of the tuyères and completing the thermal reaction of the reactants of said mixture to oxide of carbon in the tuyères in advance of emission from the tuyères into the hearth charge; simultaneously flowing an annular stream of carbon monoxide through the tuyères from the inlet to the outlet of the tuyères and so as to form an annular envelope along the tuyère walls that surround the jets of fuel and oxygen therein; thereafter bringing said thermal reaction products into contact with iron ore of said blast furnace hearth, and passing the gases thereof upwardly through the furnace charge of iron ore, flux, and carbon introduced therewith as aforesaid through the throat of the furnace; and withdrawing the so-produced blast gas from the upper part of the furnace shaft.

4. A method as claimed in claim 3, and in which the thermal reaction mixture of the axial jet and the stream of carbon monoxide flow through a path of increasing cross-sectional area in the tuyères, and enter said tuyère path at its narrowest part and issue from the wider portion of the tuyère path into the hearth charge.

5. A method as claimed in claim 4, and in which the hearth portion of the furnace charge is of greater horizontal area than the stack portion of the charge, the stack portion of the charge is centrally superimposed on the hearth portion of the charge and the tuyère burning paths are disposed over the marginal top portions of the hearth of the charge that surround the lower portion of the stack portion of the charge centrally superimposed on the hearth portion.

6. A method as claimed in claim 4, and in which the tuyère paths are insulated with elemental carbon and in which the tuyère insulation is protected from the axial jet by a cooling medium comprising a reducing medium of carbon monoxide, which issues into the hearth along with the issue of the thermal reaction mixture from the tuyère paths.

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