United States Patent [19]

Borgnat et al.

[11] **3,793,002**

[45] **Jan. 19, 1974**

[54] **METHOD OF INTRODUCING A COMBUSTIBLE AUXILIARY LIQUID INTO BLAST FURNACE AND A TUYERE FOR CARRYING OUT THE METHOD**

[75] Inventors: **Daniel Borgnat**, Senecourt; **Henri Della Casa**, Metz, both of France

[73] Assignee: **Institut de Recherches de la Siderurgie Francaise**, Saint-Germaine-en-Laye, France

[22] Filed: **Oct. 12, 1971**

[21] Appl. No.: **188,247**

[30] **Foreign Application Priority Data**

Oct. 4, 1971 France 71.36906

[52] **U.S. Cl.** **75/60**, 75/59, 266/30

[51] **Int. Cl.** **C21c 5/30**, F27d 7/00

[58] **Field of Search** 75/60, 59; 266/27, 28, 29, 266/30, 41

[56] **References Cited**

UNITED STATES PATENTS

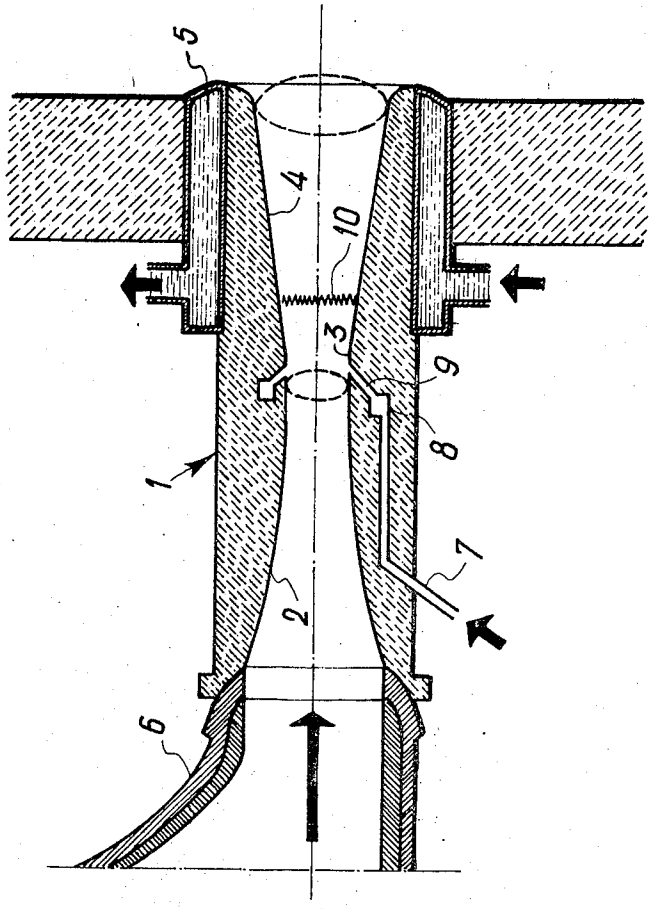
3,558,119	1/1971	Demalander	266/41
3,638,932	2/1972	Masella	75/60
3,116,143	12/1963	Reichl	266/41
3,608,881	9/1971	Yordanov	266/41
2,854,229	9/1958	Earle	266/41
3,110,584	11/1963	Sanders	266/41
3,078,084	2/1963	Foresi	266/33 R
3,236,281	2/1966	Bain	266/33 R

Primary Examiner—Hyland Bizot
Assistant Examiner—Peter D. Rosenberg
Attorney, Agent, or Firm—Michael S. Striker

[57] **ABSTRACT**

A method and tuyere for introducing a combustible auxiliary liquid into a blast furnace to partially replace coke used as reduction agent, in which the hot blast necessary for the operation of the blast furnace is fed into a tuyere passage having a convergent inlet portion and a divergent output portion at such pressure so that the hot blast reaches supersonic speed in the passage and forms a shock wave in the divergent outlet portion. The combustible liquid is introduced into the passage upstream of the shock wave forming therein so that the latter will atomize and thoroughly mix the combustible liquid with the hot air to thus cause complete combustion of the mixture.

9 Claims, 1 Drawing Figure


5
4
10
3
9
8
1
7
2
6

METHOD OF INTRODUCING A COMBUSTIBLE AUXILIARY LIQUID INTO BLAST FURNACE AND A TUYERE FOR CARRYING OUT THE METHOD

BACKGROUND OF THE INVENTION

The present invention relates to a method and apparatus for the introduction of a combustible auxiliary liquid into a blast furnace to partially replace coke utilized as reduction agent in the blast furnace.

The at least partial replacement of metallurgic coke, utilized in a blast furnace as a reduction agent for the iron ore, forms the object of numerous researches carried out by metallurgists. This problem is at the present time especially urgent due to the difficulty of obtaining the necessary coke. It has therefore been attempted to replace coke to a maximum degree by an auxiliary combustible material which is cheap and which is adapted to yield by combustion a reduction gas or which is adapted to be transformed into a reduction gas under the effect of heat. Such researches have been limited either to provide the tuyeres with which the blast furnaces are equipped with means for injecting combustible liquid, such as fuel oil, or to provide parallel to the tuyeres burners for combustion of fuel oil. These researches resulted in arrangements permitting, to a certain degree, injection of fuel oil into a blast furnace. Nevertheless, the experimentations carried out have quickly shown that the quantity of fuel oil which can be injected with efficiency by such techniques into the blast furnace is limited. In fact, a rapid deterioration of the ratio of replacement of coke by fuel oil has been ascertained when the quantity of the injected fuel oil has been increased. The ratio of replacement is understood as the quantity of coke saved by unit of combustible liquid. It was quickly ascertained that this limitation resulted from only partial combustion of the fuel oil, which in turn resulted in a formation of carbon black or soot which remained unburned due to the reducing atmosphere in the blast furnace.

To more clearly explain the problem of such an injection, the phenomena which take place when fuel oil is injected in a blast furnace will be shortly explained. Due to the heating of the combustible material injected into the hot blast and due to the presence of oxygen, the combustible material may be submitted to the following transformations:

The heavy hydrocarbons are vaporized and cracked into light hydrocarbons which in turn are decomposed into hydrogen and sometimes in carbon black. These transformations due to the heating of the liquid fuel result in products which are surrounded by oxygen of greater or smaller amount and therefore liable to burn by producing CO, CO_2, H_2, and H_2O. At the end of the tuyeres, where an oxidizing atmosphere exists, the combustion which takes place produces substantially only CO_2 and H_2O, however, due to the presence of coke of high temperature, and therefore active, the environment will become reductive and the gas quits the zone of combustion in the form of CO and H_2. Nevertheless, one can distinguish two cases of combustion; the first case corresponds to a combustion of the hydrocarbons in CO and H_2 without formation of carbon black; this case is the theoretical ideal case which one tries to approach. In the second case the cracking of the hydrocarbons results in formation of carbon black before the combustion will be complete. Part of the fuel oil will therefore leave the zone of combustion

under the form of hydrogen and carbon black. It is this second case which is encountered in actual practice when it is attempted to increase the quantity of injected fuel oil by means known in the art.

It will therefore be understood that the ratio of replacement cannot be increased without means which will prevent the formation of carbon black, that is a total combustion before cracking. The principal conditions indispensable to obtain a complete combustion are to obtain the best possible mixture of combustion air and combustible material as well as a stabilization of the resulting flame.

It has been established that none of the presently known techniques, be it the utilization of burners provided with pulverized fuel or with a liquid auxiliary fuel or the utilization of tuyeres in which the blast passing therethrough is subjected to rotation to assure a proper mixture of the fuel and the combustion sustaining agent permits to obtain such a complete combustion of a considerable quantity of fuel.

Applicants have taken a completely different approach to the problem of introducing auxiliary liquid fuel into the tuyeres of a blast furnace and obtaining complete combustion of the fuel. The solution of the problem has been based on the principle of supersonic flow of fluids and the utilization of the properties of shock waves for atomizing the fluid.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide for a process which permits to introduce into a blast furnace a quantity of combustible auxiliary liquid, to thereby replace coke as reduction agent, and to completely combust this thus introduced auxiliary liquid, which approaches as far as possible the theoretical quantity thus introducible, and an arrangement which permits to carry out the process of the present invention.

With this object in view, the present invention comprises a method for introducing into a blast furnace an auxiliary combustible liquid to partially replace coke, utilized in the blast furnace as a reduction agent, and in which combustion of the combustible auxiliary liquid is carried out in the tuyere. The method mainly comprises the steps of blowing hot blast necessary for the operation of the blast furnace through a tuyere having a convergent inlet and a divergent outlet portion, regulating the blowing of the blast through the tuyere so that the air reaches supersonic speed in the tuyere and forms a shock wave in the divergent portion thereof, injecting the combustible auxiliary liquid into the blast while the latter is at supersonic speed in order to utilize the sudden variation of the pressure and the turbulence created by the shock wave to atomize the combustible liquid and to thoroughly mix it with the blast and finally causing complete combustion of the thus obtained mixture.

It is also an object of the present invention to provide a tuyere for a blast furnace which comprises a passage for the blast having a convergent inlet portion, a sonic neck and a divergent outlet portion axially aligned with each other, means for feeding the blast at such a pressure into the inlet portion of the passage so that the blast will locally reach supersonic speed in the passage and form a shock wave in the divergent portion thereof, and means for feeding the combustible liquid into the divergent portion upstream of the shock wave forming

therein so as to atomize the combustible liquid and to mix it with the blast and to cause complete combustion of the mixture.

Finally, it is also an object of the present invention to provide a blast furnace for the production of pig iron in which the means for blowing the blast into the furnace are constituted by tuyeres having a profile adapted to carry the blast therethrough at a speed which will locally obtain supersonic speed and produce a shock wave and which are provided with means for injecting a combustible liquid into the hot air upstream of the shock wave.

The invention, as understood, consists in a complete modification of the traditional conditions of blowing the hot blast into a blast furnace and by the substitution of new norms specifically studied to favorize introduction of increased quantities of fuel oil into the blast furnace.

The inventors have found that it is possible to obtain the indispensable combustion conditions, as outlined above, in order to obtain an increased replacement ratio, by the use of tuyeres of the type which produce shock waves and to replace at the same time the standard assembly of tuyeres for a blast furnace by the tuyeres realized according to the aforementioned principle. In this way a new assembly concept directed towards the object to obtain a maximum possible replacement ratio has been arrived at and at the same time a new concept for the conditions of blowing the hot blast into the furnace and the necessary tuyeres for this purpose has been obtained.

The tuyere for carrying out the process outlined above comprises an internal passage having a convergent outlet portion followed by a sonic neck and extended by a divergent outlet portion. If a hot gas, such as blast, is supplied at a pressure, determined as a function of the characteristics of the tuyere, is introduced into the inlet portion of the passage, the blast is accelerated until it attains supersonic speed, and a shock wave will be formed in the divergent portion of the passage in which a sudden return of the flow of the gas to subsonic speed occurs. The formation of the shock wave will have two beneficial effects, on the one hand, it will provoke an extreme fine atomization of the combustible fluid and its intimate mixing with the blast, and on the other hand, it will also provoke an anchoring of the flame at this region so as to stablize the flame. In addition, the formation of a shock wave will produce a zone of turbulence which considerably favors the homogenization of the fuel and the combustion supporting blast.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The single FIGURE illustrates schematically an axial cross-section of a tuyere according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing, it will be seen that the tuyere according to the present invention, which is constructed to permit injection of fuel oil into the blast furnace, mainly comprises a metallic body **1** of substantially cylindrical configuration which is formed with an axial passage therethrough. This passage comprises a convergent inlet portion **2**, a sonic neck **3** and a divergent outlet portion **4** axially aligned with each other. The free end of the outlet portion **4** opens into the blast furnace, only partially shown in the FIGURE. The free end portion of the divergent passage **4** which is in contact with the hot zone of the blast furnace is cooled by means of a cooling jacket **5**, surrounding this part of the body **1**, into which a cooling fluid, for instance water, is fed in and out as indicated by the arrows in a manner well known in the art. Conduit means **6** are connected to the inlet portion **2** of the passage for feeding the blast under pressure into the passage from a supply of such blast, for instance from heat recuperators well known in the art.

Feeding of fuel into the tuyere is carried out by means of a conduit **7** extending through the body **1** and opening in an annular chamber **8** which surrounds the passage and which communicates with the latter in the region of the sonic neck **3** through ducts **9**. The position of the shock wave which will form in the tuyere is schematically indicated at **10** in the drawing.

It is to be understood that the drawing is strictly schematic and that the various elements and the dimension thereof are illustrated in the drawing only to clearly show the principle of the present invention. It is also evident that such a tuyere has to be calculated in accordance with the different parameters necessitated by the specific blast furnace to which it is connected. Evidently, for a blast furnace designed to function under certain given conditions there exist certain necessary parameters such as the generating temperature or the temperature of the blast introduced into the passage, which is substantially equal to the temperature at the region of the bustle pipe of the blast furnace, the static pressure of ejection of the blast, i.e., the pressure in the blast furnace at the region of the tuyeres, and the mass output of each tuyere.

These parameters can be obtained for each blast furnace and on the basis of these parameters, a person skilled in the art can evidently calculate, by means of well known formulas of the physic of fluids, the necessary profile of the passage through the tuyere and determine the inlet pressure for the hot gas and therewith the pressure which is necessary to realize a zone of supersonic speed in the tuyere and the formation of a shock wave.

To prove the possibility of the aforementioned technique, the inventors have carried out tests with a tuyere model of reduced scale while realizing the combustion of fuel oil in an enclosure and taking the analysis of the reduced gas as criterion to test the quality of the combustion. A tuyere for a blast furnace through which a hot blast of 10,000 m^3/h is blown has been taken as a reference for these tests and with a tuyere at a reduced scale of 1 : 5, as used during the tests, a pressure of ejection of 1 bar has been realized. Considering the reduced scale of the tuyere, a hot blast with a temperature of 600°C in the amount of 150 Nm^3/hour has been

blown through the tuyere while at the same time an increasing quantity of fuel has been fed into the interior of the tuyere passage while continuously controlling the analysis of the gas of combustion and while continuously observing any appearance of any carbon black which, as pointed out above, is the main obstacle for the injection of increased fuel oil with an advantageous replacement ratio.

These tests have shown that it is possible to inject up to 170 grams of fuel oil per cubic meter of air into the interior of the passage of the tuyere without appearance of any carbon black which appeared only in small quantities beyond the aforementioned value.

The result thus obtained clearly shows the importance of the aforementioned technique, since it was possible to nearly double the stoichiometeric quantity, corresponding to the quantity of fuel oil which one can burn per Nm^3 under formation of CO_2 and H_2O, which is 90 grams per Nm^3, while obtaining a combustion without formation of carbon black.

This fact has been confirmed by the results of the analysis of the dry combustion gas obtained, the composition of which was as follows:

$CO = 19\%$
$CO_2 = 4\%$
$H_2 = 12\%$
$N_2 = 65\%$
(Humidity = 8%)

A gas rich of CO and H_2 without carbon black has been obtained, the composition of which closely approaches the theoretical composition which permits to obtain a ratio of replacement of 1 : 1.

To more clearly show the importance of the process according to the present invention and the possibility offered by the same to obtain better practical results than with the methods known, two cases will be compared in which the blast furnace is respectively charged with low grade ore (ore from the region or Lorrain in France) and in which the blast furnace is charged with a high grade ore.

During use of low grade ore, it was up to now possible to inject 130 – 160 Kg fuel oil per ton of pig iron obtained into the furnace and during use of high grade ore it was possible to inject 100 – 120 Kg of fuel oil per ton of pig iron obtained. The process according to the present invention, however, permits to increase these values respectively to 270 Kg per ton of pig iron in the first case and to 190 Kg per ton of pig iron in the second case, therefore a substantially increase, i.e., an increase of about 80 percent of the quantity of the injected fuel oil. By considering the amount of industrial coke utilized in blast furnaces, it is evident that such an increase of the quantity of fuel oil, by means of which a corresponding quantity of coke can be replaced, is of extreme economic interest.

It is also emphasized that the tuyeres for carrying out the process of the present invention are extremely simple in construction in that they do not require any movable component and will therefore stand up properly under extended use.

The process according to the present invention permits therefore to introduce into a blast furnace a maximum amount of auxiliary combustible liquid and to obtain the combustion thereof into a gas with a maximum content of CO and H_2.

It will be understood that each of the elements described above or two or more together may also find the useful application in other types of tuyeres differing from the types described above.

While the invention has been illustrated and described as embodied in a tuyere constructed to feed a maximum amount of auxiliary combustible liquid into a blast furnace, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims:

1. A method for introducing into a blast furnace an auxiliary combustible liquid to partially replace coke utilized in the blast furnace as a reducing agent, said method comprising the steps of blowing a blast necessary for the operation of the blast furnace in axial direction through a tuyere having a convergent inlet portion, a sonic neck portion and a divergent outlet portion, all of said portions being aligned along a common axis; regulating the blowing of the blast so that the air reaches in said divergent outlet portion supersonic speed and forms a shock wave in said divergent outlet portion in a region thereof spaced from said sonic neck; and injecting into said tuyere between said sonic neck and the region of said divergent outlet portion the auxiliary combustible liquid into the blast while the latter is at supersonic speed so as to automize the liquid by said shock wave and to thereby intimately mix it with the blast, thereby causing fast and complete combustion of the thus-obtained mixture without appreciable formation of carbon black.

2. A method as defined in claim **1** wherein said combustible liquid is introduced into the tuyere upstream of the shock wave forming therein.

3. A method as defined in claim **1**, wherein said combustible liquid is fuel oil.

4. A tuyere as defined in claim **3**, wherein said passage is formed in a metal body of generally cylindrical configuration, and wherein said means for introducing the combustible liquid into said passage comprises an annular chamber surrounding said passage and opening into the latter in the region of said sonic neck and conduit means for feeding the liquid into said chamber.

5. A tuyere as defined in claim **4**, and including a cooling jacket surrounding said body at least in the region of said outlet portion of said passage, and means for feeding a cooling fluid into and out of said jacket.

6. A method as defined in claim **1**, wherein said combustible liquid is introduced into said divergent portion of the tuyeres.

7. A tuyere for introducing a blast into a blast furnace comprising a passage for the blast having a convergent inlet portion, a sonic neck, and a divergent outlet portion axially aligned with each other along a common axis; means for feeding a blast in axial direction only and at such a pressure into said inlet portion of said passage that the blast will move only in axial direction in a region of said divergent outlet portion, spaced from

said sonic neck, at supersonic speed and form a shock wave in said region of said divergent outlet portion; and means for feeding a combustible liquid into said divergent outlet portion upstream of said region wherein the shock wave is formed so as to atomize the combustable liquid by said shock wave and to intimately mix it with said blast, thereby causing fast and complete combustion of the mixture without appreciable formation of carbon black.

8. A tuyere as defined in claim **13,** wherein said tuyere is a Laval-type tuyere having a convergent inlet portion and a divergent outlet portion of substantially the same angle of divergence than said inlet portion.

9. In a blast furnace, a combination comprising a plurality of tuyeres for introducing a blast into the blast furnace, each of said tuyeres comprising a passage for the blast having a convergent inlet portion, a sonic neck, and a divergent outlet portion axially aligned with each other along a common axis; means for feeding a blast in axial direction only and at such a pressure into said inlet portion of said passage that the blast will move only in axial direction and reach in a region of said divergent outlet portion, spaced from said sonic neck, supersonic speed and form a shock wave in said region of said divergent outlet portion; and means for feeding a combustible liquid into said divergent outlet portion upstream of said region wherein the shock wave is formed so as to atomize the combustible liquid by said shock wave and to intimately mix it with the blast, thereby causing fast and complete combustion of the mixture without appreciable formation of carbon black.

* * * * *