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[54] **METHOD AND APPARATUS FOR INJECTING LIQUID FUEL INTO A SHAFT FURNACE**
14 Claims, 2 Drawing Figs.

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[50] **Field of Search** 263/29, 30; 266/29

[56] **References Cited**

UNITED STATES PATENTS

3,383,099 5/1968 Rehder 263/29

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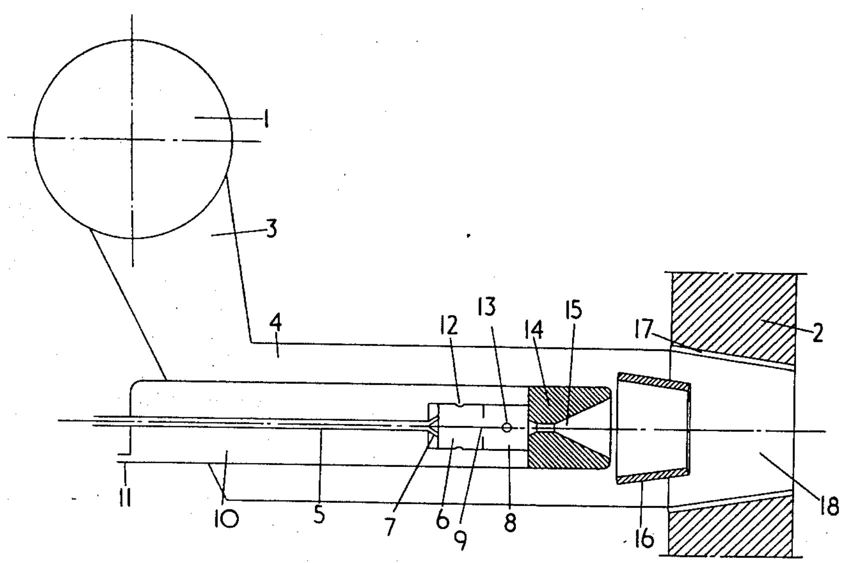
ABSTRACT: A method for the injection of a liquid fuel into a shaft furnace, in which a jet of fuel is introduced into a chamber where it is atomized by a jet of compressed gas. The mixture of fuel and gas is then passed through at least one further chamber in which a further jet of compressed gas completes the atomization of the fuel. The mixture is then caused to converge and then diverge before being subjected to the action of a hot oxidizing gaseous fluid, whereby the fuel is burned before being injected into the furnace.



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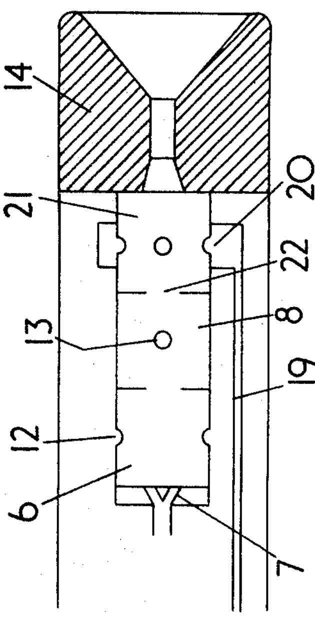

FIG. 2

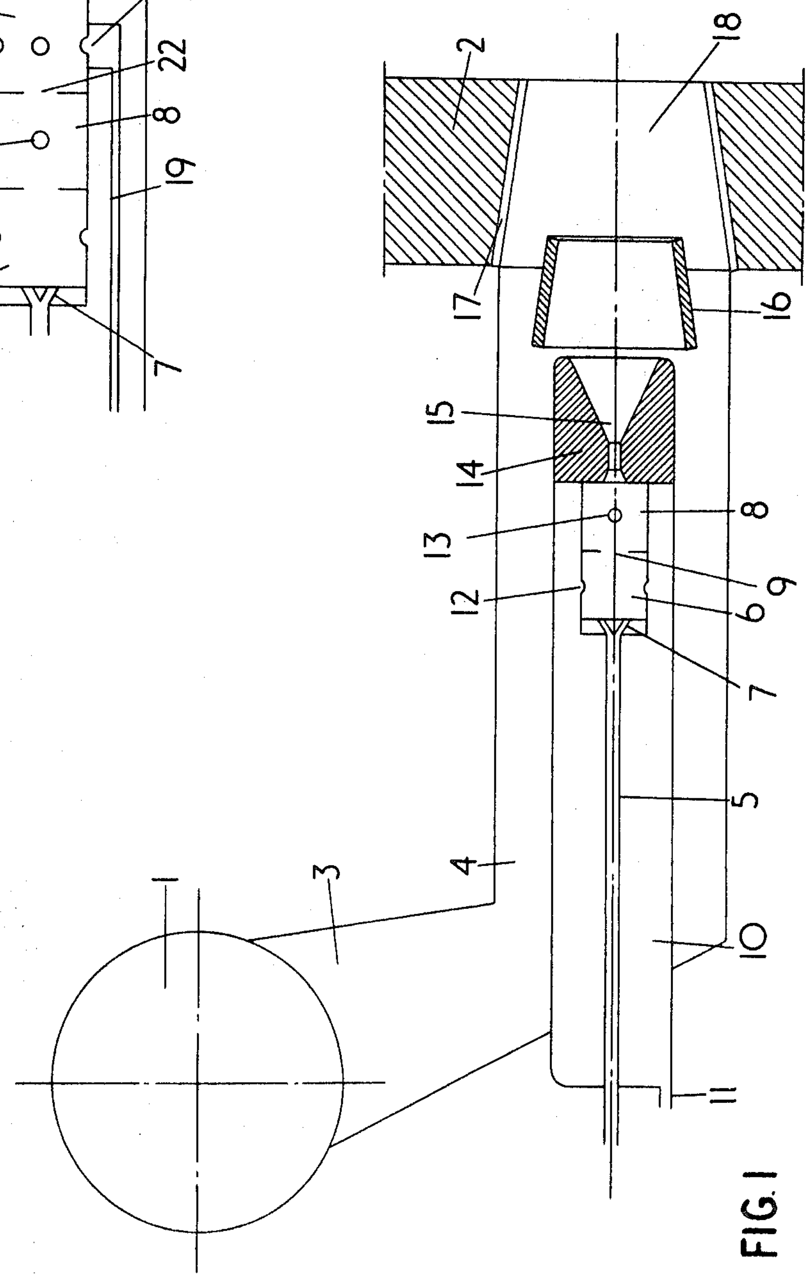

FIG. 1

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METHOD AND APPARATUS FOR INJECTING LIQUID FUEL INTO A SHAFT FURNACE

The invention relates to a method and apparatus for the injection of liquid fuel into a shaft furnace.

It is well known that by injecting liquid fuel into a shaft furnace, in particular into a blast furnace, it is possible, in good utilization conditions, to decrease the coke rate to a substantial extent and to exercise some control over the running of the blast furnace. In spite of this, however, with the fuel injectors customarily used in blast furnace operation, frequently one does no more than ensure the introduction of a more or less compact jet of fuel oil into the current of hot air, the dispersion and atomization of the jet of fuel in the current of air not being in general very extensive.

Moreover, the amount of fuel which can actually be used by this method is, relatively speaking, low. In actual fact, beyond a certain rate of flow which is rapidly reached, the jet of fuel is scarcely dispersed at all and the fuel no longer burns before leaving the combustion zone of the blast furnace; in addition the degree of atomization of the fuel is dependent on the rate of flow of the hot air.

In order to be able to draw the maximum benefit from the injection, while overcoming the above-mentioned disadvantages, it has already been proposed to preheat the fuel and even to start its combustion a short time before it enters the furnace. It has also already been suggested that the fuel should be atomized and mixed with an oxidizing gas, for the purpose of facilitating the combustion of the one by the other. Some of these methods have, however, still retained certain disadvantages, in particular the appearance of cracking under conditions which would lead to a blocking up of the injectors. Certain other of these methods would require high pressure devices for obtaining satisfactory atomization of the fuel. Others, which while permitting partial combustion of the fuel before its entry into the furnace, would require a comparatively long dwell time of the oxidizing gas and the fuel in the injection nozzle. The same applicant, in a previous patent specification has already described a method adapted to overcome the majority of these disadvantages in a highly satisfactory way.

According to the invention, there is provided a method for the injection of fuel into a shaft furnace, the method comprising the steps of introducing a jet of liquid fuel into a chamber, in which the pressure on the liquid is reduced, injecting into the chamber a jet of compressed gas which atomizes the fuel and mixes with it, passing the mixture through one or more secondary chambers in series with the first chamber in each of which it is subjected to the action of one or more jets of compressed gas, which jets enhance the atomization of the fuel, directing the mixture of fuel and gas through a convergent/divergent device, and subjecting the mixture at the outlet of the said device to the action of a hot oxidizing gaseous fluid in a proportion such that substantially all the fuel present in the mixture is burned before being introduced with the fluid into the shaft furnace.

This method ensures a high calorific combustion yield and increases the working life of the device in which the combustion starts up and develops. Moreover, the degree of atomization of the fuel and accordingly the homogeneity of the fuel/compressed gas mixture are particularly high.

In accordance with an advantageous variation of the method of the invention, the jets of compressed gas are preheated before entering the mixing chambers, which enables the gasification of the fuel to be started, this preheating being carried out preferably by means of the hot oxidizing gaseous fluid which is preferably hot air.

In accordance with another advantageous variation of this method, the oxygen content of the jets of compressed gas is higher the nearer the chamber into which they are directed is to the convergent/divergent device, in front of it, the jet of compressed gas in the chamber immediately preceding the convergent/divergent device being substantially richer in oxygen than the jets in the other chambers.

In this latter variation the combustion of the fuel cannot give up intense heat in the first mixing chambers, with the result that any risk of the destruction of these chambers by abnormal increase in temperature is ruled out; combustion develops mainly in the last chamber, which is less likely to be destroyed since the gases produced by the combustion escape immediately from the chamber, and in practice there is scarcely time for them to raise the temperature of the walls of the said last chamber.

The invention also provides an injector by which it is possible to put the above-described method into operation; such an apparatus is shown diagrammatically in the accompanying drawings.

In the drawings:

FIG. 1 shows an injector for liquid fuel; and

FIG. 2 shows a detail of the injector illustrating an alternative embodiment of the injector.

In the drawings, which have been given by way of example only and are not to scale, the section of a circular air main of a blast furnace is shown at 1. A branch 3,4 of this main is attached by a tuyere 17 to the wall 2 of a blast furnace and it is accordingly possible for hot air to be blown into the furnace through the orifice 18.

The horizontal portion 4 of the branch surrounds a fuel injector which is constructed as follows; a fuel line 5 opens out through orifices 7 into an expansion chamber 6, where the fuel is atomized by means of jets of compressed gas. The mixture of fuel and gas is conveyed from the expansion chamber 6 to a secondary chamber 8, where it is again subjected to the action of jets of compressed gas. These gases are supplied via the conduit 10 fed at 11, and penetrate into the chambers through the orifices 12 and 13; an orifice 9 gives communication between the chambers 6 and 8; the secondary chamber 8 opens out into a convergent/divergent device 14/15, arranged to face the orifice 18 formed in the wall of the furnace. A convergent nozzle 16, which is axially displaceable, enables the length of the flame to be regulated.

In an alternative embodiment of injector, as indicated in FIG. 2, two secondary chambers 8,21 are in series with the chamber 6 and communicate with each other through an orifice 22. The mixture of fuel and compressed gas passes from the chamber 8 through the orifice 22 and is again subjected to the action of jets of compressed gas from orifices 13. The mixture is further subjected to the action of an oxygen-rich gas injected through orifices 20 opening out from a gasline 19. Partial combustion of the fuel occurs in the chamber 21 and the mixture emerges through the convergent/divergent device 14.

The injector forming the subject of the invention has the essential features that it comprises:

a. A line intended to supply liquid fuel to a first chamber through at least one orifice;

b. One or more secondary chambers in series communicating with the first chamber through an orifice, and the secondary chambers communicating successively with each other by one or more orifices in such a way that the fuel penetrating into the first chamber through the fuel line passes successively through the first chamber then the secondary chamber or chambers;

c. A channel opening out, preferably tangentially, into the chambers through suitable inlets. This channel is intended to supply a compressed gas to the chambers, the orifices being orientated in such a way that the jets of compressed gas meet and atomize the jet or jets of fuel introduced into the first chamber and that the jets of gas meet in each secondary chamber the fuel/compressed gas mixture issuing from the prior chamber.

d. A convergent/divergent device obturating the last secondary chamber in such a manner that the fuel and compressed gas mixture cannot leave this chamber except by passing through the convergent/divergent device.

e. A channel intended to supply hot, oxidizing gaseous fluid to the furnace. This channel is connected to the furnace, for instance, by means of a tuyere, and the convergent/divergent device sealingly opens out into the interior of the channel.

In accordance with an advantageous modification of the injector of the invention, the last chamber, i.e. that immediately in front of the convergent/divergent device, has means for supplying a gas rich in oxygen, which means may open out into the last chamber through, for instance, inlets as used for the compressed gas or through separate type inlets.

Again in accordance with a modification of the invention, a frustoconical nozzle is arranged convergently at the outlet of the convergent-divergent device so as to leave a free space between the convergent/divergent device and the nozzle, the nozzle being displaceable substantially along the axis of the injector, this having the advantage of making it possible to regulate the length of the flame issuing from the injector.

In accordance with a still more advantageous modification of the injector of the invention, the fuel line is arranged in the interior of the compressed gas channel which is itself disposed in the interior of the channel for the hot, oxidizing gaseous fluid.

The injector illustrated in the accompanying drawing enables the compressed gas to be preheated by the hot, oxidizing gaseous fluid, while protecting the fuel from any possible cracking effect resulting from premature heating. Moreover, the compressed gas cools the internal wall of the channel **10** and accordingly protects it from the heat of the fluid.

The data given below are examples only to facilitate comprehension of the particularly interesting advantages of the injector forming the subject of the invention. A liquid fuel injector was constructed in accordance with the above description with an injection capacity in an industrial furnace of 300 kg./hr. of extra heavy fuel, heated to 100° C.; this injector functioned at a fuel pressure of 9 kg./$cm.^2$ at entry; the compressed gas used for atomizing and gasifying the fuel was injected at 6 kg./$cm.^2$, at a rate of flow of 30 nm^3/hr., and the hot air supplied to the tuyere of the blast furnace was at a pressure between 1 kg./$cm.^2$ to 1.2 kg./$cm.^2$.

The injector described was subjected to a laboratory test by which it was possible to check its functioning characteristics. During the course of this test, the injector was placed in a tubular electric furnace, heated to 900° C., to simulate the thermal conditions existing in the interior of a blast furnace tuyere. Compressed air was circulated in an envelope protecting the injector externally, and the air became heated, while still protecting the injector. Once the air came into contact with the fuel oil in the mixing chamber it started not only a fine dispersion of the fuel oil but also the heating and gasification of the latter, with the result that at the outlet of the injector the fuel had the form not only of a shower of fine droplets but also the form of a thick mist of gasified fuel oil; this mixture ignited spontaneously on contact with a flame, or even with a red hot bar of steel. The combustion flame of the fuel oil remained quite stable, even in the absence of a flame or of a hot ignition point. The combustion flame had an elongated shape, which was advantageous for using this injector in the blast furnace. The flame moreover was brilliant and its aspect indicated that good combustion was taking place.

After the preliminary test, the injector was introduced into a blast furnace tuyere, and its performance was compared to that of the standard injectors with which the other tuyeres of the same furnace were equipped. At these tuyeres, equipped with standard injectors, it was not possible to observe any combustion flame. The fuel was in actual fact liquid all the time, and unignited when it passed into the combustion zone in the interior of the furnace. On the other hand, at the tuyere equipped with the new injector, it was possible to observe a fuel combustion flame already in the interior of the tuyere, i.e. before the combustion zone of the coke in the furnace. It was possible to raise the rate of fuel oil supplied to this new injector to a value 30 percent higher than with standard injectors.

The rapid combustion of the liquid fuel achieved thanks to the injector described above, enables larger amounts of liquid fuel to be usefully injected without the combustion of the fuel being affected by the normal variations in the running of the furnace, e.g. by normal variations in the rate of flow of hot air to the individual tuyeres.

This result constitutes a particularly important advantage of the method of the invention, and in actual fact plays a part in reducing the coke rate to a substantial extent.

I claim:

1. In a method for injecting fuel into a shaft furnace, comprising introducing a jet of liquid fuel into a first chamber, atomizing the fuel by means of a jet of compressed gas wherein the gas mixes with the atomized fuel, causing the mixture to converge and then diverge, then subjecting the mixture to the action of a hot oxidizing gaseous fluid, and introducing the mixture of fuel gas and oxidizing fluid into the shaft furnace: the improvement comprising the steps of passing mixture of fuel and compressed gas from said first chamber immediately through at least one secondary chamber; introducing at least one further jet of compressed gas into said secondary chamber to augment the atomization of the fuel; and after causing the mixture to converge and then diverge, introducing the hot oxidizing gaseous fluid into the mixture in such a proportion that substantially all the fuel present in said mixture of fuel and compressed gas is burned before being introduced along with said oxidizing fluid into the furnace.

2. The method as claimed in claim **1**, comprising the further step of preheating at least one of said jets of compressed gas before being introduced into a chamber.

3. The method as claimed in claim **2**, in which said preheating is performed by said hot oxidizing gaseous fluid.

4. The method as claimed in claim **1**, in which the jet of compressed gas introduced into the last chamber through which the fuel and compressed gas mixture passes is substantially richer in oxygen than the jet of compressed gas in the prior chamber.

5. In an injector for the injection of liquid fuel into a shaft furnace, comprising a first chamber, a fuel line for supplying liquid fuel to said first chamber through at least one orifice, at least one inlet into said first chamber, a channel for injecting a compressed gas into said first chamber through said inlet, a convergent/divergent means through which the liquid fuel and compressed gas pass, and a channel for supplying a hot oxidizing gaseous fluid to the furnace, the convergent/divergent means sealingly opening out into the interior of said channel for hot oxidizing gaseous fluid: the improvement being at least one secondary chamber having an orifice, the secondary chamber communicating with said first chamber through the orifice; at least one injection inlet through which said channel for the compressed gas opens into said secondary chamber; said inlet in said first chamber being orientated such that the compressed gas injected therein mixes with and atomizes the fuel supplied into said first chamber; said inlet in said secondary chamber being orientated such that the compressed gas meets the fuel and compressed gas mixture issuing from said first chamber and augments the atomization of the fuel; said convergent/divergent means being positioned adjacent said secondary chamber so that the fuel and compressed gas mixture can only leave said secondary chamber by passing through the said means.

6. The injector as claimed in claim **5**, further comprising a frustoconical nozzle arranged convergently at the outlet of said convergent/divergent means so as to leave a space between said means and the nozzle, said nozzle being displaceable substantially along the axis of the injector.

7. The injector as claimed in claim **5**, further comprising means for supplying a gas rich in oxygen to the secondary chamber immediately before said convergent/divergent means.

8. The injector as claimed in claim **5**, wherein said fuel line is arranged in the interior of said compressed gas channel, which channel is arranged in the interior of said channel for the hot oxidizing gaseous fluid.

9. In an injector for the injection of liquid fuel into a shaft furnace, comprising a first chamber, a fuel line for supplying liquid fuel to said first chamber through at least one orifice, at least one inlet into said first chamber, a channel for injecting a compressed gas into said first chamber through the said at least one inlet, a convergent/divergent means through which the liquid fuel and compressed gas pass, and a channel for supplying a hot oxidizing gaseous fluid to the furnace, the convergent/divergent means sealingly opening out into the interior of said channel for hot oxidizing gaseous fluid: the improvement being a series of secondary chambers comprising at least a first secondary chamber and a last secondary chamber, said first secondary chamber communicating with said first chamber through an orifice; further injection inlets through which said compressed gas channel opens into said secondary chambers, said injection inlet into said first chamber being orientated such that the compressed gas injected therein mixes and atomizes the fuel supplied into said first chamber; said further injection inlets being orientated such that the compressed gas injected into each secondary chamber meets the fuel and compressed gas mixture issuing from the previous secondary chamber in the series, whereby the atomization of the fuel is augmented; said convergent/divergent means being arranged adjacent to the last secondary chamber in the series such that the fuel and compressed gas mixture can only leave said last secondary chamber by passing through said means.

10. The injector as claimed in claim **9**, further comprising a frustoconical nozzle arranged convergently at the outlet of said convergent/divergent means so as to leave a space between said means and the nozzle, said nozzle being displaceable substantially along the axis of the injector.

11. The injector as claimed in claim **9**, further comprising means for supplying a gas rich in oxygen to said last secondary chamber.

12. The injector as claimed in claim **9**, wherein said fuel line is arranged in the interior of said compressed gas channel which is arranged in the interior of said channel for the hot oxidizing gaseous fluid.

13. The method as claimed in claim **1** comprising the further step of expanding said liquid fuel as it enters said first chamber by reducing the pressure on the liquid fuel.

14. The method as claimed in claim **5** wherein said inlets in the first and secondary chambers for compressed gas are tangential to the chamber.