METHOD FOR COMBUSTION OF A LIQUID FUEL WITH STAGED ATOMIZATION

The present invention relates, on the one hand, to a method for combustion of a liquid fuel comprisisng the steps for producing a spray (10) of the liquid fuel by injecting a main stream (3) of an atomizing gas is contact with the liquid fuel (4), the said method being characterized an that at least one secondary stream (11) of atomizing gas is injected close to t spray (10) is order to produce a secondary atomization of the said spray (10) prior to its contact with a jet of oxidizer in order to carry out the combustion of the spray, and, on the other, to a burner impl such a combustion method.

Figure 1

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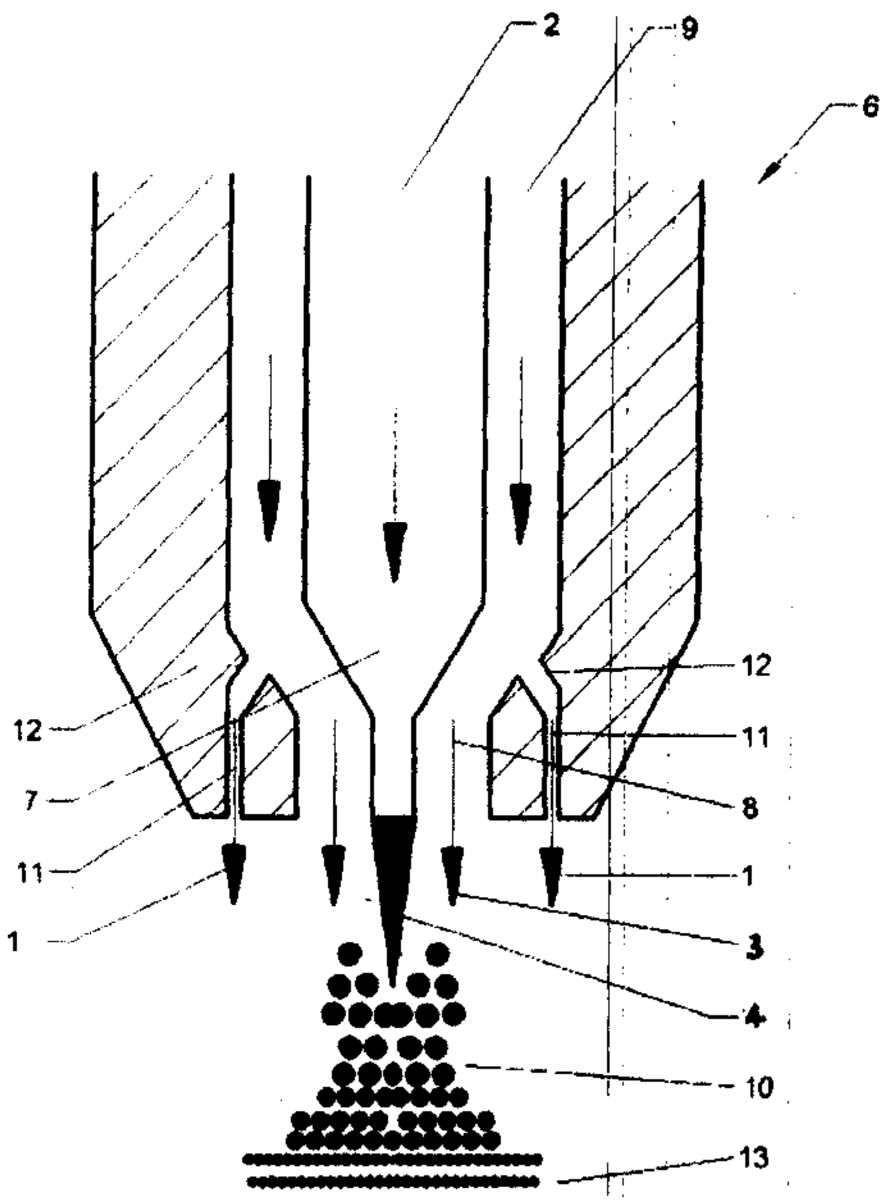

Fig. 1

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CLAIMS

1. Method for combustion of a liquid fuel comprising the steps for producing a pray (10) of th liquid fuel by injecting a main stream (3) of ar atomizing gas in contact with the liquid fuel (4), the sai method being characterized in that at least one secondary stream (1, 5) of atomizing gas is injectec close to the spray (10) in order to produce a secondary atomization of the said spray (10) prior to its contact with a jet of oxidizer in order to carry out the combustion of the fuel.

2. Combustion method according to Claim 1, characterized in that the secondar tream (1) of atomizing gas is injected in a direct parallel to the injection direction of the liquid fuel.

3. Combustion method according , to Claim 1, characterized in that the secondary stream (5) of atomizing gas is injected in an oblique directio converging towards the injection direction of the liquid fuel

4. Combustion method according to any one or Claims 1 to 3, characterized in that the secondary stream (1, 5) of atomizing gas is injected so as to produce a turbulent flow.

5. Combustion method according to any one of Claims 1 to 4, characterized in that the atomizing gas flow rate in the secondary stream (1, 5) of atomizin gas represents between 20% and 70% of the total flo rate of atomizing gas.

6. Combustion method according to any one o Claims 1 to 5, characterized in that the secondary stream (1, 5) of atomizing gas is "divided into a

plurality of streams injected in a uniformly distributed manner and equidistant around the liquid fuel stream (4).

7. Combustion method according to any one of Claims 1 to 6, characterized in that the oxidizer jet is divided into a primary oxidizer jet and a secondary oxidizer jet, the primary oxidizer jet being injected close to the liquid fuel spray in order to cause a first incomplete combustion, the gases issuing from this first combustion still comprising at least part of the fuel, while the secondary oxidizer jet is injected at a distance I_2 from the fuel spray which is higher than the distance between the liquid fuel jet and the primary oxidizer jet closest to the liquid fuel spray, in order to enter into combustion with the part of the fuel present in the gases issuing from the first combustion.

8. Burner comprising at least one liquid fuel injection means (7) combined with at least one atomizing gas injection means (8) in order to produce a fuel spray (10), and at least one oxidizer injection means, characterized in that it compr at least one secondary atomizing gas injection means (11, 12, 14) arranged close to the fuel injection means.

9. Burner according to Claim 8, characterized in that the secondary atomizing gas injection means (11, 12, 14) is obtained by bypassing a common atomizing gas feed (9).

10. Burner according to either of claims 8 and 9, characterized in that the secondary means (11, 12, 14) is oriented parallel to or obliquely to the fuel injection means (7).

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L'AIR LIQUIDE SOCIETE ANONYME POUR L'ETUDE
ET L'EXPLOITATION DES PROCEDES GEORGES CLAUDE
No.

20 JUL 2006

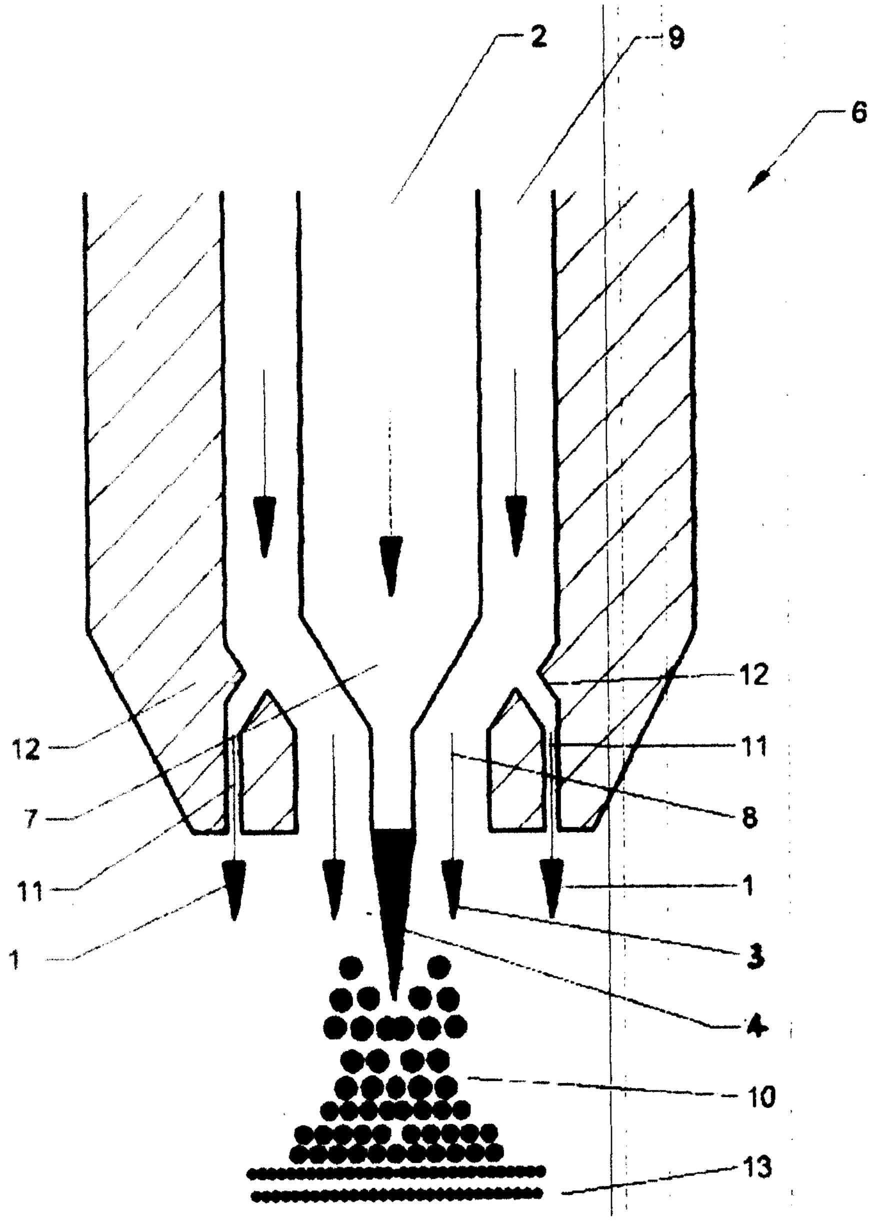

Fig. 1

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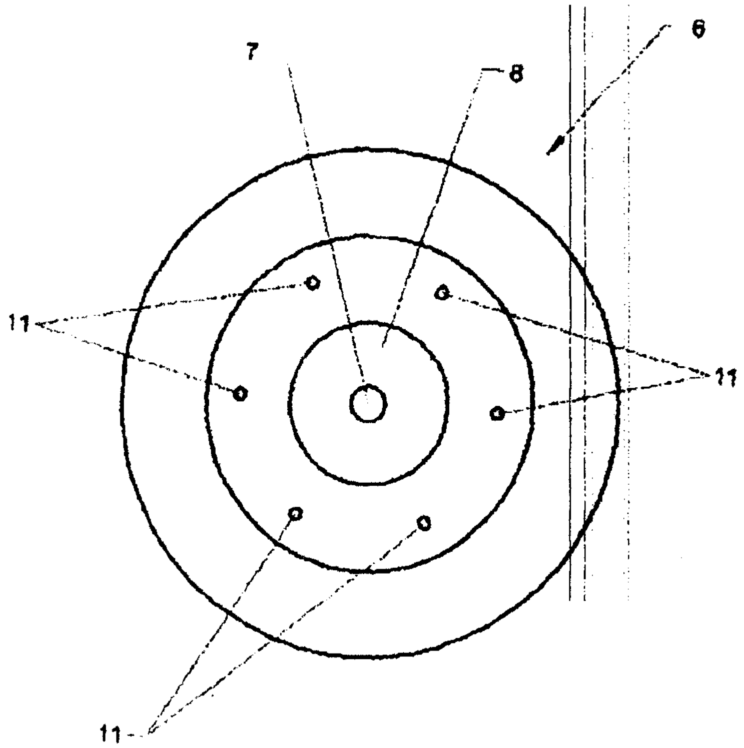

Fig. 2

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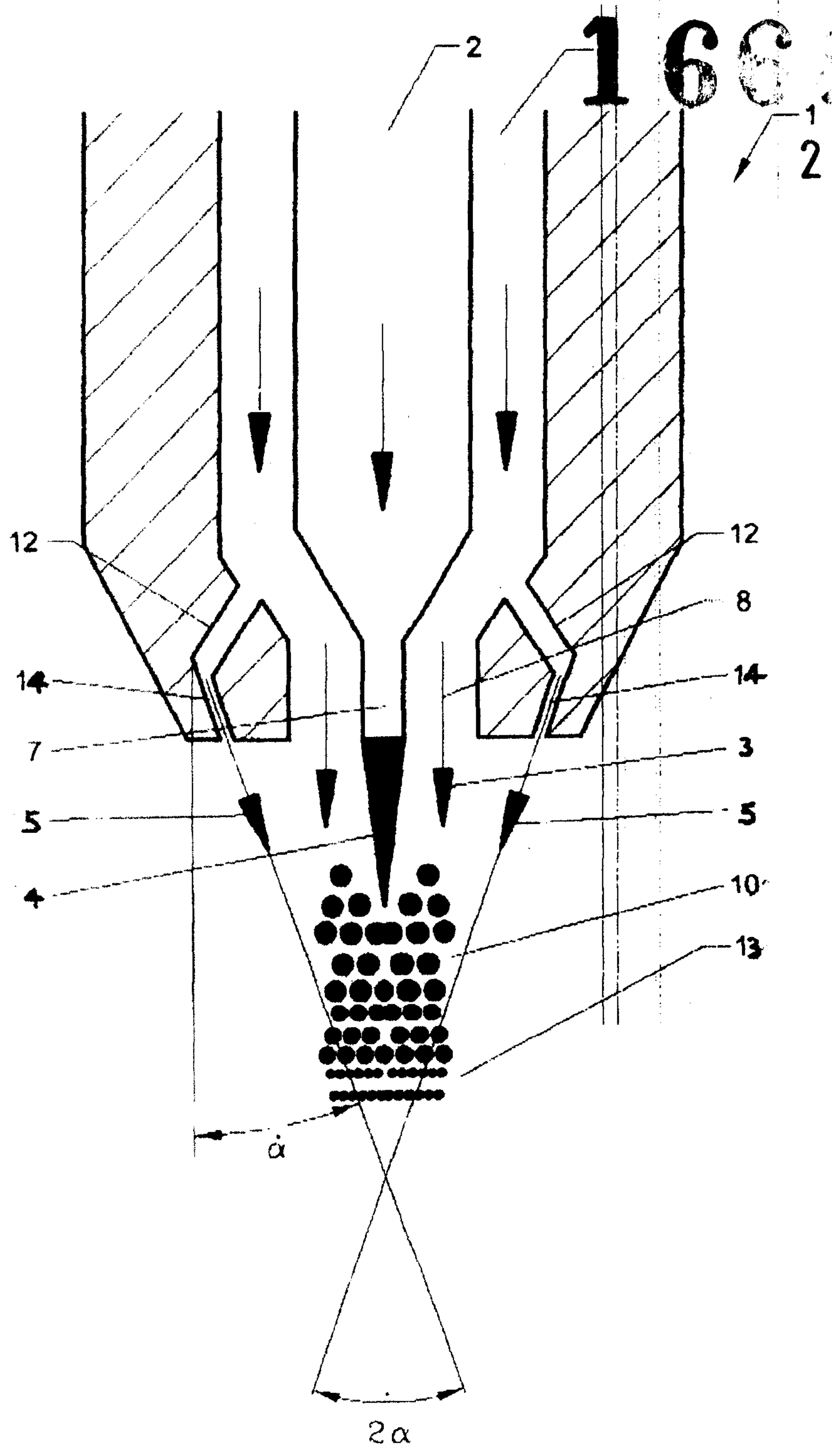

Fig. 3

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The present invention relates to a method for combustion of a liquid fuel, and to a burner implementing the same.

During the installation of a combustion system for an industrial furnace, for example, one of the major concerns is to optimize the combustion efficiency by optimally controlling the flame properties, while meeting the needs of the heated method in terms of heat transfers and minimizing air pollutant releases.

The two-phase combustion of a liquid fuel by an oxidizing gas comprises two main steps before the actual combustion takes place. In the first step, it is necessary to atomize the liquid fuel using an atomizing gas injected so as to destabilize the liquid fuel stream and to form a fuel spray ith a higher contact surface area with the oxidizer in order to promote the combustion. The atomizing gas used may be air, oxygen, steam or even natural gas, for example. It is then necessary for the liquid fuel drops thus formed to evaporate before the fuel burns with the oxidizer. Since the fuel drop vaporization time it longer than the reaction time, the mixture of the reagents and, in consequence, the combustion properties, essentially depend on the characteristics of the fuel spray, particularly the size of the fuel drops formed.

The spray characteristics depend on the type of injector used. Most injectors use a high speed differential between the atomizing gas and the liquid fuel to destabilize the fuel and for the spray. Two types of injector are available according to whether a high speed flow is imposed on the fuel or the atomizing gas, that is, mechanical injectors in which the fuel is subjected to high pressure and flow at high speed through a small-diameter orifice, and injectors call d "dual fluid" injectors in which a fuel jet flows at a relatively low speed and is destabilized by a high speed flow of atomizing gas. However, mechanical injectors are little used because, on the one hand, the incur higher risks of blocking of the fuel injection orifice by deposits, and on the other, a limited flow range due to the high cost of the compressors needed to reach high liquid pressures.

Dual fluid injectors can allow for very high atomizi gae flow speeds. In this category, a distinction in made between air-assisted atomizers, operating with lo flow rates of gas ejected at very high speed, and spray atomizers characterized by lower atomizing gas fl speeds but higher flow rates. Two fluids can be mixed in a confined environment (internal mixing injector) or outside the injection system (external mixi ng injector).

Furthermore, the liquid fuel flow may optionally be oriented to form a film on an appropriate surface before its contact with the atomizing gas flow. In this case, the injector is called a prefilmi g atomizer, with prior formation of a liquid film, and in the opposite case, a plain jet atomizer, with ful liquid flow.

The most commonly used injectors in oxy-combustion are injectors of the dual flow type with spraying with an atomizing gas speed lower than 200 m. with extern al mixing, and plain jet injectors

The combustion properties of a spray produced by such injectors are mainly controlled by changing the relative atomizing gas and liquid f speeds. Is In doing so, the mean drop size of the fuel spray is modified, and consequently, the vaporization time compared with the combustion reaction I time is als changed. The drop size and vaporization time control the mixing of the evaporated fuel with the oxidizer and are hence very important combustion parameters, determining particularly whether the combustion is complete or not. However, although controlling the injection speeds serves to adjust the properties of the spray and of the two-phase combustion to adapt them to the heated process, such injectors still have a lack of flexibility.

For example, it is difficult to effectively control the cooling of the injector. In fact, an increase in the atomizing gas flow rate results in a reduction in the mean drop size, and consequently, a closer reaction zone and hence overheating of the injector.

Moreover, for an excessively high atomizing gas flow rate, the atomization mode may go from a fibre mode, that is, with a fully developed liquid cone, to a superpulse mode, that is, with a short and truncated liquid cone. In this case, the reactio zone is liable to stabilize in the immediate neighbourhood of the burner and cause its destruction. Moreover, an excessively high atomizing gas speed can also cause instability of the flame. In fact, it has been demonstrated that the stability of the flame could be related to the ratio of the mixing time to the characteristic time of the combustion chemistry, the flame being stable when this ratio is above 1- In the case of an excessive increase in the atomizing ga s speed, the mixing time becomes shorter than th e characteristic time of the combustion chemistry, and the stability condition is no longer satisfied.

Another drawback is that the spray characteristic affect several parameters which ar therefore not possible to control independently f one another. Thus, it is not possible to control the spray drop size and spray angle independently, characteristic bot h dependent on the ratio of the momentu of atomizing gas to that of the fuel. More particularly, if this momentum ratio is lower than 5, an increase in th atomizing gas flow rate simultaneously results in a decrease in the drop size and a widening of the spra angle, the flame being liable to interact with those of adjacent burners.

Another drawback appears in the case in which a hig viscosity fuel is used. In this case, a simpl atomizing gas stream injected in a ring around the liquid fuel stream does not permit uniform atomizatio producing a spray with uniform drop sizes. This cause irregular combustion and problems of flame stabilization.

It is the object of the present invention to overcome the abovementioned drawbacks and therefore consists of a method for combustion of a liquid fuel comprising the steps for producing a spray of the liquid fuel by injecting a main stream of an atomizing gas in contact with the liquid fuel, the said method being characterized in that at least one secondary stream of atomizing gas is injected close to the spray in order to produce a secondary atomization of the said spray prior to its contact with a jet of oxidizer in order to carry out the combustion of the fuel.

Thus, for the same total atomizing ga flow rate, the flow rate of the first atomizing stream is decreased, causing the formation of a spray with a higher size of the drops formed in the neighbourhood of the injector The fuel drops of the first spray then undergo a second atomization, leading to a modified spray with smaller drops. A first spray having already been formed, the secondary atomization is more effective, particularly in the case of a high viscosity fuel, and entrains th drops of the modified spray further from the injector. Due to this staged atomization of the liquid fuel, th combustion reaction takes place further from the injector, thereby decreasing the risks of burner overheating and destruction. It is important to observe that in the case in which e burner has a retractable injection head, the secondary atomization allows it to operate with a higher retraction. Moreover, the atomizing gas flows thereby multiplie permit more effective cooling of the burner. The injector service life is thereby increased and its maintenance reduced.

This improvement in cooling the injector is particularly advantageous in the case in which the atomizing gas used is oxygen, a gas for which the risks of overheating are high.

Furthermore, the presence of a secondary atomization stream reduces the dependence between the drop size (flame length) and the spray angle (flame width) by limiting the increase of the latter. The flame length can therefore be controlled more easily, hile limiting the risks of interaction with adjacent burner flames.

A further advantage of the invention is the reduction of emissions of NOx compounds. In fact, the flame temperature obtained is more uniform, so that NOx formation is reduced. This process is accentuated by a better dilution of the reagents and combustion products thanks to the secondary atomizing gas stream

According to a first exemplary embodiment of the method, the secondary stream of atomizing gas is injected in a direction parallel t the injection direction of the liquid fuel.

According to a second exemplary embodiment of th method, the secondary stream of atomizing gas is injected in an oblique direction converging towards the injection direction of the liquid fuel. This makes it possible to control the spray angle more accurately the modified spray angle being equal t twice the angle between the secondary atomizing gas stream injection direction and the fuel flow direction. Advantageously, the secondary atomizing gas stream is injected at an angle of between 0 and 60°, praferably at an angle of between 0 and 30°.

Optionally, adjusting means can be provided for orienting the secondary atomizing gas am injection direction as regards the liquid fuel injection direction in order to increase the flame width, and consequently, the heat transfer to the heated process, if necessary.

Advantageously, the secondary stream f atomizing gas is injected so as to produce a turbulent flow. . Thus, the turbulent flow improves the dilution of the reagents and combustion products andj rther reduces the emissions of NOx compounds.

Preferably, the secondary atomizing ga flow rate represents between 20% and 70% of the total flow rate of atomizing gas.

Advantageously, the secondary stream of atomizing gas is divided into a plurality of streams injected in a uniformly distributed manner and *equidistant around th* liquid fuel stream. The injection can be carried out inter alia, by a concentric flow around the fuel injection or by a plurality of openings terminating in the burner head and uniformly distributed around the fuel injection. More precisely, the ma atomizing gas stream is injected coaxially around the liquid fuel while the secondary stream is ected via the plurality of openings.

The method according to the invention is ideal for the staged combustion process in which the oxidizer ill injected and divided into several streams introduced at various distances from the fuel spray, as described i particular in WO 2004/094902. Thus, the oxidizer jet can be divided into a primary oxidizer jet and a secondary oxidizer jet, the primary oxidizer jet being injected close to the fuel spray in order to cause i first incomplete combustion, the gases issuing from this first combustion still comprising at least part of the fuel, while the secondary oxidizer jet is injected at a distance I from the fuel spray which is higher than the distance between the fuel Spray and the primary oxidizer jet closest to th fuel spray, in order to enter into combustion with the part of th fuel present in the gases issuing m the first combustion. The invention also covers the case is which a third oxidizer jet is injecte at a distance I from the fuel spray which is longer t the distance I_1.

The method according to the invention IS ideal for two phase burners an which the atomizing as ie injected, on the one hand, at a speed at least 10 times highe than the fuel injection speed, and on the other, with an atomizing gas mass flow rate higher than 10% of th fuel mass flow rate.

The present invention further relates to a burner implementing the preceding two-phase co method the said burner comprising at least one fuel injection means combined with at least one atomizing gas injection means in order to produce a fuel spray, and at least one oxidizer injection means characterized in that it comprises at least one secondary atomizing gas injection means arranged close to the fuel injection means. It should be observed that in the case of a burner with highly separated jets, such a burner comprises a primary oxidizer injection means, * secondary oxidizer injection means arranged at a distance from the fuel injection mea that is; longer than that of the primary injection means, and optionally, a tertiary oxidizer injections mean arranged at the edge of the burner.

Advantageously, the secondary atomizing gas injection means is obtained by bypassing a common atomizing gas feed. The choice of the bypass diameter serves to define a ratio between the primary atomizing gas stream and the main stream. Further advantageously, the secondary injection means is oriented parallel to or obliquely to the fuel injection means.

The implementation of the invention will be better understood from the detailed description given below with reference to the drawing appended here to in which:

- Figure 1 is an enlarged partial schematic representation of a longitudinal cross section of an atomization head of a burner according to the invention;
- Figure 2 is a front view of the atomizatio head in Figure 1; and
- Figure 3 is an enlarged partial schematic representation of a longitudinal cross section of another atomization head of a burner ding to the invention.

A combustion method according to the invention is implemented by a burner comprising a spray-guide atomization head 6 with external mixing as shown in Figures 1 and 2. This atomization head 6 comprises:

- an ejection line 7 for a liquid fuel stream 4 delivered by a fuel feed 2; and
- an atomizing gas ejection li line 8 concentric with the fuel ejection line 7 and connected to an atomizing gas feed 9 and terminating in contact with the fuel stream 4 in order to produce a liquid fuel spray 10 under the action of a ma atomizing gas stream 3.

Furthermore, the atomization head 6 ha six secondar ejection channels 11 oriented parallel to the fuel ejection line 7 and to the atomizing gas ejection line 8. These six secondary ejection hannels 11 are uniformly distributed around the ejection lines , 8 and are designed to create secondary atomizing gas streams 1 tapped off from the atomizing gas feed 9 by bypass channels 12. Under the effect of these secondary atomizing gas streams 1, the liquid fuel spray 10 thereby undergoes a second atomization producing a modified spray 13. This modified spray 13 is then contacted with an oxidizer stream (not shown), optionally divided into a primary stream and a secondary stream, to carry out the c of the fuel. A tertiary oxidizer feed may also be located at a relatively long distance from the atomization head 6 and is used to inject oxygen at high speed in order to obtain a sufficient dilution of the reagents before the main combustion zone and thereby to prevent an excessive formation of thermal NOx compounds. Experiments have demonstrated that such a burner, in which 50% of the total oxygen was injected at the tertiary feed level, served, all other things remaining equal, to obtain a flame stabilization distance equal to about four times the flame stabilization distance of a conventional injector without secondary atomizing gas stream. This longer stabilization distance serves to reduce the overheating of the atomization head 6. Furthermore, it has also been demonstrated that the flame obtained was more uniform and longer due to the delayed atomization, the spray 10 having a larger drop size than a spray issuing from a conventional burner while the modified spray 13 has a smaller drop size and better diluted and hence more uniformly distributed drops.

The more uniform flame thus obtained consequent reduces the temperature difference etween the hot spots and the cold spots.

A significant reduction of NOx compound emissions by a burner equipped with an atomization head 6 according to the invention has also been demonstrated. A reductio by a factor of between 1.2 and 1.5, depending on th oxidizer distribution selected, can be obtained for th same total atomizing gas flow rate. This reduction can be explained by the lag of the react explainedb yt h el a go thanks to the invention.

As a variant, an atomization head 1, as shown in, Figure , differs from the atomization head 6 only in the fact that it comprises secondary ejection lines 14 obliquely oriented by an angle a to the fuel flow direction. The angle a is advantageously between 0 and 60°, preferably between 0 and 30°. These secondary jection lines 14 deliver secondary atomizing gas stream 5 which, with the spray 10, form a modified spray 13 having a spray angle of 2a. Such an atomization hea 1 is suitable for more accurate adjustment of the flame width.

Although the invention has only been described in connection with particular embodiments, it is quite obvious that it is not limited thereby and that it comprises all the technical equivalents of the means described and of their combinations if these fal within the scope of the invention.