Title: LOW NOx BURNER

Abstract: The present invention is a burner tip to be used in a furnace for the combustion of fuel gas in the combustion zone of said furnace, comprising a burner tube having a longitudinal axis and having a downstream end and an upstream end for receiving the fuel gas, wherein, the furnace comprises means to introduce an effective amount of air into the combustion zone to cause the combustion of the fuel gas, the burner tube extends through an opening in the wall or floor into the combustion zone, the burner tube comprises a plurality of primary ports to deliver the primary fuel gas in the combustion zone, said primary ports are located in the combustion zone in order to create the fuelLean combustion zone, a bluff body is attached to the tube, located close to the primary ports which deliver the primary fuel gas and between said ports and the upstream end of the burner tube, the bluff body is designed to produce, in the vicinity of the ports which deliver the primary fuel gas, an air speed as low as possible, advantageously lower than the flame speed, such as the said primary fuel gas is given sufficient residence time to ignite, the burner tube comprises a plurality of secondary ports to deliver the secondary fuel gas in the combustion zone, said secondary ports are located in the flue gas zone (or outside the combustion zone) in order to create a fuel-rich zone, said secondary ports are located between the primary ports and the downstream end, optionally other ports are located after the secondary ports having regards to the fuel gas flow from the upstream end to the downstream end. The flame stabilization is ensured by the bluff body, for example fins or a perforated plate, which has been welded to the tip just below the primary fuel ports. The flame stabilizer creates a recirculation zone for the air in which the primary fuel is given sufficient residence time to ignite.
LOW NOx BURNER

[Field of the invention]

5 The present invention relates to a low NOx burner. Nitrogen oxides NO and NO2 are produced in three different ways in furnaces and boilers:
- fuel NOx: based on the nitrogen that is present in liquid and solid fuels
- prompt NOx: produced early in the flame, but in small quantities
- thermal NOx: produced at very high temperatures

Thermal NOx is the dominant mode for furnaces that use gaseous fuels, for example steam cracking furnaces that use mixtures of methane with 5-30 vol% hydrogen. So in order to achieve low emissions of nitrogen oxides (NOx) with a gaseous fuel it is necessary to reduce the peak flame temperature in order to reduce the thermal NOx production. Research has shown that the highest formation of thermal NOx occurs around the stoichiometric ratio, which means that ratio where the oxygen requirements for complete combustion are precisely fulfilled. The NOx formation is significantly less in case the amount of oxygen is much higher than necessary for complete combustion (fuel – lean combustion) or in case the amount of oxygen is much less than necessary for complete combustion (fuel – rich combustion). Burner technology to reduce thermal NOx therefore usually consists of methods to divide the combustion zone into fuel-lean and fuel-rich zones. This can be accomplished by staging the fuel into different injection zones (fuel staging) or by staging the combustion air into different zones (air staging). The present invention relates to a fuel staging method.

[Background of the invention]

30 Examples of fuel staging patents are:
US 5,195,884
US 5,275,552
US 7,198,482
US 6,695,609
These burners consist of various arrangements where separate primary fuel tip(s), with or without additional flue gas recirculation methods, are combined with separate staged fuel tips which are located around the burner tile.

In US 5,195,884 the burner apparatus includes a refractory burner tile having a base portion and a wall portion, the wall portion extending into the furnace, surrounding a central area of the base portion and having exterior sides which are slanted. Means are attached to the burner tile for mixing a portion of the fuel gas with the air and discharging the resulting mixture into a primary burning zone in the furnace from within the space defined by the wall portion of the burner tile. At least one secondary fuel gas nozzle means positioned for discharging the remaining portion of the fuel gas adjacent to an external slanted side of the wall portion whereby the fuel gas mixes with flue gases and air in the furnace and burns in a secondary burning zone therein. US 5,275,552 is very close to US 5,195,884.

In US 6,695,609 the burner apparatus is basically comprised of a housing having a burner tile attached thereto and means for introducing air therein. The burner tile has an opening therein with a wall surrounding the opening which extends into a furnace space. The exterior sides of the wall are divided into sections by radially positioned baffles with alternate sections having the same or different heights and slanting towards the opening at the same or different angles. Primary fuel gas mixed with flue gases and air is discharged through the burner tile. Secondary fuel gas is discharged adjacent to the external slanted wall sections whereby the secondary fuel gas mixes with flue gases in the furnace space. The resulting fuel gas-flue gases streams mix with the fuel gas-flue gases-air mixture discharged through the burner tile and the resulting mixture is burned in the furnace space. US 7,198,482 is very close to US 6,695,609.
A problem of these fuel tips is overheating and internal fouling/coking caused by thermal cracking of the fuel. This applies especially to the staged fuel tips. They are typically exposed to the furnace radiation because they need to entrain flue gas in order to create a fuel rich combustion zone. In order to minimize radiation exposure it is necessary to minimize the exposed surface and keep the tips short.

The present invention simplifies the design by combining the primary and secondary fuel stages into one single riser, without increasing the fouling tendency. Basis of the design is a bluff body attached to the burner tip, located close to the ports which deliver the primary fuel gas, said bluff body is designed to produce, in the vicinity of the said ports, an air speed as low as possible, advantageously lower than the flame speed, such as the said fuel gas is given sufficient residence time to ignite. The bluff body also provides near-burner recirculations, which improves ignition and flame stability. Secondary ports, to deliver the secondary fuel gas, are located in the flue gas zone (or outside the combustion zone) in order to create a fuel-rich zone.

US 4,604,048 (and also US 4,645,449) relates to a burner in which fuel is discharged from a nozzle disposed within a burner housing, air is introduced into the housing which is mixed with the fuel and the resulting fuel-air mixture is ignited and combusted. A first portion of the fuel is discharged from the nozzle through one or more orifices therein whereby the fuel mixes with air and provides an ignition zone adjacent the nozzle. A second portion of the fuel is discharged from the nozzle by way of one or more additional orifices whereby the second portion of fuel is distributed in a turbulent pattern which exposes the fuel to a quantity of air in excess of that required for the stoichiometric burning thereof and causes the fuel to burn in a primary combustion zone. The remaining portion of the fuel is discharged from the nozzle by way of one or more additional orifices which are surrounded by one or more fuel discharge recesses whereby high velocity jets of fuel shielded by slow moving fuel are produced and the fuel is distributed within and downstream of the primary
combustion zone. This portion of the fuel is mixed with excess air from the primary combustion zone and combustion products and is burned in a secondary combustion zone substantially shielded from direct contact with incoming air by the primary combustion zone. The nozzle by which fuel is ejected is surrounded by a cone including openings. Primary and secondary fuel are ejected by the same ejector (or nozzle). It has nothing to see with the present invention in which the primary ports and the secondary ports are separated.

US 2004 0006991 discloses a dual fuel premix nozzle and method of operation for use in a gas turbine combustor. The dual fuel premix nozzle utilizes a fin assembly comprising a plurality of radially extending fins for injection of gas fuel and compressed air in order to provide a more uniform injection pattern and homogeneous mixture. The premix fuel nozzle includes a plurality of coaxial passages, which provide gaseous fuel and compressed air to the fin assembly. This is the contrary of the present invention in which there is no premixing of fuel and air, only fuel gas is sent through the burner tube.

US 5813846 describes a flat flame burner having flow passages for admitting fuel and air to a burner tile. A structure for producing a rotational flow cooperates with a divergent burner tile in order to produce a radially-divergent flame with a very small axial component and a high degree of entrainment of inert combustion products in a furnace. For example, the flow rotating structure can be integral with a body design, alone or in combination with a discrete structure such as an offset air connector, a "half moon" inlet spinner, a swirler or a flame stabilizer 34 located close to the primary fuel ports as illustrated in fig 3. This is the contrary of the present invention in which the bluff body is designed to produce, in the vicinity of the ports which deliver the primary fuel gas, an air speed as low as possible, advantageously lower than the flame speed, such as the said primary fuel gas is given sufficient residence time to ignite. The present burner is preferably used in high temperature furnace environments. In said US 5813846 at col 3 lines 48+ is cited "At operating temperatures above the auto-
ignition temperature of the fuel, where combustion is considered to be self-sustaining, the use of the primary injector 44 is not required and 100% of the fuel can be supplied through the secondary injector 48. In this operating mode, NOx levels are reduced to about 30 ppmv." Maybe this burner is efficient but it has nothing to see with the present invention in which fuel gas is continuously delivered through the primary and secondary nozzles.

EP1852656A1 describes a method for fuel combustion wherein the main fuel stream (1) is divided into three smaller streams (or groups of streams) (2), which subsequently one after each other fall in various sections into an air flow (3) in the casing, wherein the time of the distribution along the distributing tube from the fall of the first stream (or the first group of streams) to the fall of the last stream (or the last group of streams) is the period Tfeed, then the fuel and air are mixed in a flow during the period Tmix, wherein "poor" homogeneous air/fuel mixture is created, and this mixture then falls in the hot combustion products in a half-limited (with one opened end) combustion tube (4) where the mixture burns during the period Tcomb and combustion gases are created and the heat is released, wherein the streams (or groups of streams) of the fuel are brought to the air stream according a certain relation. In this prior art combustion takes place only at the end of the premixing zone. It has nothing to see with the burner of the present invention in which there is a combustion close to the primary ports.

[Brief summary of the invention]

The present invention is a burner tip to be used in a furnace for the combustion of fuel gas in the combustion zone of said furnace, comprising a burner tube having a longitudinal axis and having a downstream end and an upstream end for receiving the fuel gas, wherein,

- the furnace comprises means to introduce an effective amount of air into the combustion zone to cause the combustion of the fuel gas,
• the burner tube extends through an opening in the wall or floor into the combustion zone,
• the burner tube comprises a plurality of primary ports to deliver the primary fuel gas in the combustion zone, said primary ports are located in the combustion zone in order to create the fuel-lean combustion zone,
• a bluff body is attached to the tube, located close to the primary ports which deliver the primary fuel gas and between said ports and the upstream end of the burner tube,
• the bluff body is designed to produce, in the vicinity of the ports which deliver the primary fuel gas, an air speed as low as possible, advantageously lower than the flame speed, such as the said primary fuel gas is given sufficient residence time to ignite,
• the burner tube comprises a plurality of secondary ports to deliver the secondary fuel gas in the combustion zone,
• said secondary ports are located in the flue gas zone (or outside the combustion zone) in order to create a fuel-rich zone,
• said secondary ports are located between the primary ports and the downstream end,
• optionally other ports are located after the secondary ports having regards to the fuel gas flow from the upstream end to the downstream end.

The flame stabilization is ensured by the bluff body, for example fins or a perforated plate, which has been welded to the tip just below the primary fuel ports. The flame stabilizer creates a recirculation zone for the air in which the primary fuel is given sufficient residence time to ignite.

The purpose of said secondary ports and optional subsequent ports to deliver the fuel gas is to stage the combustion zone into fuel-lean and fuel-rich zones. This approach reduces the NOx formation chemistry

Advantages of the invention:
- All functions are combined into one tip. This makes it cheap and easy to retrofit into existing burners.

- It is an ideal design for applications where additional gases need to be incinerated in process furnaces. These off-gas streams are not constant and are usually injected through raw gas nozzles. These raw gas nozzles may lead to increased NOx numbers. The integral tip proposed here is a much better candidate.

- Due to its design the tip stays very clean inside. Fouling is usually one of the main issues hampering low-NOx burners.

- It is flexible enough to allow multiple fuel stagings and increased tip length.

[Detailed description of the invention]

Fuel gas means any gas capable to burn but advantageously comprises essentially methane or mixtures of methane with hydrogen (e.g. 5 to 30 vol % in methane), or mixtures of methane with hydrogen and/or purge gas recovered in a steam cracking plant. The purge gas comprises hydrocarbons having up to 5 carbon atoms.

As regards the burner tube it would not depart from the scope of the invention to have a burner type having a non circular cross section area. The burner type can be horizontal or vertical. The secondary fuel ports can be circular or slotted. Circular ports are preferred as they entrain more flue gas.

As regards the bluff body it can be any shape which produce, in the vicinity of the ports which deliver the primary fuel gas, an air speed as low as possible, advantageously lower than the flame speed, such as the said primary fuel gas is given sufficient residence time to ignite. The bluff body can be a
plurality of fins or a cone having a symmetrical axis essentially in line with the longitudinal axis of the burner tube. The fins and/or the cone can be made of a solid or perforated plate.

In a preferred embodiment the burner tip is reduced in diameter after each fuel gas injection to maintain a high velocity inside the tip. In other words a burner tip having primary ports and secondary ports has a reduced diameter between the primary ports and secondary ports as compared with the section between the upstream end and the primary ports. The reduction in diameter is done gradually (e.g. over a length of about 3 to about 4 diameters) in order to prevent recirculations and dead zones. The internal diameters are advantageously chosen such that a minimum fuel gas velocity of about 30 m/s, preferably about 40 m/s is achieved over the entire length of the burner tip. This means that if tertiary fuel ports are added, the tip is again reduced in diameter.

These design features prevent overheating and cracking of the fuel inside the tip. Additional protection against overheating can be provided by covering the exterior surface in a ceramic liner. Due to burner tip design the staged fuel riser length can be varied in order to achieve the optimal NOx reduction. By increasing the length it will entrain more oxygen-depleted flue gas from the firebox and achieve better dilution of the combustion reactants.

Figure 1 shows an example with primary and secondary fuel ports and a conical perforated plate type flame stabilizer.
CLAIMS

1. Burner tip to be used in a furnace for the combustion of fuel gas in the combustion zone of said furnace, comprising a burner tube having a longitudinal axis and having a downstream end and an upstream end for receiving the fuel gas, wherein,
   - the furnace comprises means to introduce an effective amount of air into the combustion zone to cause the combustion of the fuel gas,
   - the burner tube extends through an opening in the wall or floor into the combustion zone,
   - the burner tube comprises a plurality of primary ports to deliver the primary fuel gas in the combustion zone, said primary ports are located in the combustion zone in order to create the fuel-lean combustion zone,
   - a bluff body is attached to the tube, located close to the primary ports which deliver the primary fuel gas and between said ports and the upstream end of the burner tube,
   - the bluff body is designed to produce, in the vicinity of the ports which deliver the primary fuel gas, an air speed as low as possible, such as the said primary fuel gas is given sufficient residence time to ignite,
   - the burner tube comprises a plurality of secondary ports to deliver the secondary fuel gas in the combustion zone,
   - said secondary ports are located in the flue gas zone (or outside the combustion zone) in order to create a fuel-rich zone,
   - said secondary ports are located between the primary ports and the downstream end,
   - optionally other ports are located after the secondary ports having regards to the fuel gas flow from the upstream end to the downstream end.

2. Burner tip according to claim 1 wherein the bluff body is a plurality of fins.
3 Burner tip according to claim 1 wherein the bluff body is a cone having a symmetrical axis essentially in line with the longitudinal axis of the burner tube.

4 Burner tip according to claim 2 or 3 wherein the fins and/or the cone are made of a solid or perforated plate.

5 Burner tip according to any one of the preceding claims wherein the bluff body is designed to produce, in the vicinity of the ports which deliver the primary fuel gas, an air speed lower than the flame speed such as the said primary fuel gas is given sufficient residence time to ignite.

6 Burner tip according to any one of the preceding claims having primary ports and secondary ports wherein the diameter between the primary ports and secondary ports is reduced as compared with the section between the upstream end and the primary ports.

7 Burner tip according to claim 6 wherein the reduction in diameter is done gradually in order to prevent recirculations and dead zones.
Drill angles:
A: 5° toward wall, 15° LEFT
B: 5° toward wall, 0° LEFT
C: 5° toward wall, 15° RIGHT

Flameholder:
perforated plate, 2 mm thick, standard hole pattern (60°)
diameter 8 mm on 9 mm pitch
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

**INV.** F23C6/04   F23D14/18  
**ADD.**  
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
F23C  F23R  F23D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database consulted during the international search (name of database and, where practical, search terms used)
EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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☐ Further documents are listed in the continuation of Box C.  
X See patent family annex

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**Date of the actual completion of the International search**  8 July 2010  
**Date of mailing of the international search report** 15/07/2010  

Name and mailing address of the ISA: European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Ridderkerk Tel. (+31-70) 340-2000, Fax: (+31-70) 340-3016  

Authorized officer  

Munteh, Louis
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