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(54) **Title:** PROCESS FOR PRODUCING FLAT FLAME BY OXY-SOLID FUEL BURNER

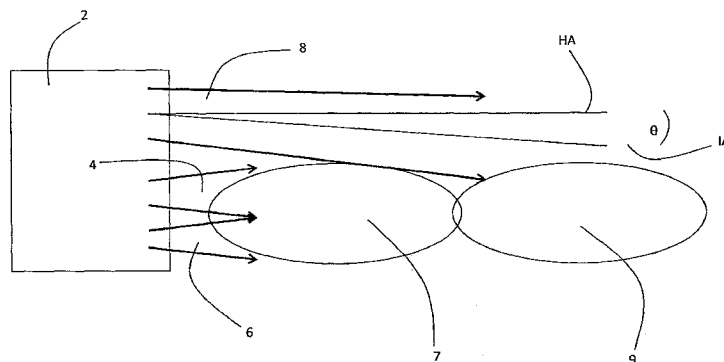


FIG 3

(57) **Abstract:** A process for producing a flat flame in an industrial melting furnace using solid fuel is provided. The flat flame is produced by a burner combusting particulate fuel by injecting a plurality of fuel streams (4) lying in a plane above a plurality of high speed primary oxidant streams (6) lying in a different plane and under a plurality of secondary oxidant streams (8) lying in another different plane. The velocity of the fuel streams (4) is decreased just upstream of the burner block front face in order to slow down the fuel streams (4) to allow a sufficiently long residence time in the furnace for satisfactory burnout and avoid accumulation of fuel particles inside the fuel nozzle.

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PROCESS FOR PRODUCING FLAT FLAME BY OXY-SOLID FUEL BURNER

Background

Field of the Invention

5 The present invention relates to solid fuel burners, and in particular to an oxy-solid fuel burner able to produce a flat flame shape (a flame sheet) that is especially suited for the requirements of melting furnaces and related processes, especially glass furnaces.

10 Related Art

 For melting processes in industrial melting furnaces, it is desirable to have flames with broader coverage over the molten bath (such as that of glass or metal). One potential approach is to use a flat flame.

 Typically, natural gas or oil -fired, flat flame burners produce flames three
15 times wider than conventional oxy-fuel burners. On the other hand, most conventional solid fuel burners have pipe-in-pipe configuration with or without a swirl that produces a cylindrically shaped flame, not a flat flame. A pipe-in-pipe burner with swirl is very advantageous for combustion of solid fuels because recirculation zones created by a strong swirl help maintain flame stability.
20 However, cylindrically shaped flames inherently offer less coverage of the molten bath than that required for the melting processes.

 Solid fuels, such as pet-coke or coal, are major sources of fuel in the world. Whereas petroleum coke (petcoke) is a byproduct of the petrochemical industry where it is produced as a result of the oil refining process, coal is a natural product.
25 Petcoke exhibits handling properties similar to coal.

 Different devices and methods are available today to combust coal in furnaces and boilers. Coal is usually conveyed with air or with a mixture of oxygen with flue gases ('synthetic air'). The fuel is guided to the combustion zone as primary stream. Additional oxidizer(s) is injected separately for complete
30 combustion. Depending on the swirling oxidizer and burner geometry such as quarl size, injector blockage ratio, gas velocities and momentum ratio, various mixing patterns can be achieved and sometimes different mixing patterns result in significantly different flame shape and length.

Two conventional pulverized coal burners include the swirl-stabilized pipe-in-pipe burner and the S-type burner.

The swirl-stabilized pipe-in-pipe burner has been used for more than six decades for firing a variety of coals in many boiler sizes. The burner is composed of a central nozzle to which primary oxidizer and pulverized coal is supplied. The coal is rapidly dispersed into the secondary stream by the impeller at the tip. Moderate swirl produces a cylindrical shape of flame plume.

The S-type burner was developed in 1980s. The secondary air flow and swirl are separately controlled, which enable this type of burner to be operated in higher combustion efficiency and mechanical reliability. Given the same design philosophy as a circular burner, the flame shape of the S-type burner is similar to what is expected from swirl-stabilized pipe-in-pipe burners.

After the introduction of NO_x emission regulation, a number of low NO_x burners have been developed, including those disclosed in US 4,836,772 and US 4,479,442. Since NO_x emission levels are significantly related to the basic flow mixing profiles, the International Flame Research Foundation (IFRF) recognized four different types of flames: Type 0, Type 1, Type 2, and Type 3. Type 2 can be considered to be the most common type of flame for solid fuel combustion although the others are occasionally used for a certain purpose. Although the mixing pattern is very different among these types of burners, the general burner configuration is pipe-in-pipe so that the anticipated flame shape is cylindrical. It should be also noticed that for all the cases, the secondary oxidizer, which is normally the main source of oxidizer, completely envelops primary oxidizer and fuel streams.

A lot of improvements in burner design have been made in order to conform to more strict NO_x regulation. For example, US 2005/0092220 A1 discloses a solid fuel burner which could accelerate ignition of the fuel and prevent slugging caused by combustion ash from occurring. The improvements, however, have not change the fundamental shape of cylindrical flame much.

Flat flame burners have been developed for natural gas-fired and fuel oil-fired industrial melting furnaces because they produce a large surface area, highly radiant flame over the molten bath. For example, US 5,611,682 describes a staged oxy-fuel burner for producing a generally flat fuel-rich flame overlying a

highly radiative fuel lean flame. Also, US 2010/0167219 A1 discloses production of a flat flame from a burner that includes a block cavity that transitions from an elliptical cross-section to a circular cross-section. In conventional natural gas-fired or fuel oil-fired flat flame combustion processes, the oxidizer and/or fuel are
5 injected by the burner into the furnace as a high speed jet to form a flat shape over a large area. When only one of the oxidant and fuel streams is injected as a high speed jet, the other stream is expected be entrained in the high speed jet.

There is significant uncertainty involved in directly applying the natural gas/oil flat flame concept to combustion of solid fuels, primarily due to the longer
10 ignition delay of solid fuels compared to gaseous or liquid fuels. More specifically, the technical challenge associated with solid fuel combustion is believed to arise from the difficulty in igniting the solid fuel particles. To address this issue, most solid fuel combustion burners have a pipe-in-pipe structure with a strong swirl to completely envelope the fuel stream.

15 In general, increasing the swirl to keep a flame attached to a burner will lead to a shorter flame and smaller surface area coverage over the molten bath. On the other hand, decreasing the swirl in order to achieve a longer flame and larger surface area can lead to an unstable flame.

Thus, there is a need for a burner that can achieve a stable, broad flame
20 when employing solid fuels.

Summary

There is disclosed a process for producing a flat flame in an industrial melting furnace using a solid fuel that includes the following steps. A first portion
25 of primary oxidant is injected into the furnace as two or more high speed primary oxidant streams from a front face of a burner block at a same height from a bottom face of the burner block. At least two streams of particulate fuel are injected into the furnace from the burner block front face at a same height from the burner block bottom face above the high speed primary oxidant streams, wherein
30 the stream of particulate fuel comprises particles of solid fuel fluidized with a conveying gas. A second portion of primary oxidant is injected into the furnace in the form of two or more annuli each one of which surrounds a respective one of the fuel streams. The first and second portions of primary oxidant are combusted

with the fuel streams in the furnace at a first combustion zone to produce a flat flame and incomplete products of combustion. Secondary oxidant is injected into the furnace as at least one secondary oxidant stream from the burner block front face above the injection of fuel streams. The secondary oxidant is combusted with the incomplete products of combustion at a second combustion zone. The burner block has at least two fuel passages from which the at least two streams of particulate fuel are injected into the furnace. Each of the fuel passages has a fuel nozzle extending through it to define annular passageways between inner surfaces of the fuel passages and outer surfaces of the fuel nozzles. The second portion of primary oxidant is injected into the furnace from the annular passageways. The fuel nozzles terminate at a point upstream of the burner block front face such that each of the fuel streams flows out the terminal end of an associated fuel nozzle and mixes with the second portion of primary oxidant in the fuel passageways prior to being injected into the furnace.

The process may include one or more of the following aspects:

- the secondary oxidant stream is injected downward at an angle toward the flat flame.
- the high speed primary oxidant streams are injected into the furnace at an axial velocity of 10 m/s to 50 m/s.
- the at least two fuel streams are injected into the furnace at an axial velocity of no more than 6 m/s.
- the second portion of primary oxidant is injected into the furnace with a swirl.
- the second portion of primary oxidant comprises 5-10% of a total amount of oxidant injected into the furnace by the first and second portions of primary oxidant and the secondary oxidant stream.
- the fuel stream is injected into the furnace with a swirl.
- each of the high speed primary oxidant streams is injected into the furnace with a swirl.
- the conveying gas is selected from the group consisting of air, CO₂, and flue gas.
- the at least two particulate fuel streams comprises two particulate fuel streams.

- the at least two particulate fuel streams comprises four particulate fuel streams.
- the at least two high speed primary oxidant streams comprises two primary oxidant streams.
- 5 - the at least one secondary oxidant stream comprises two secondary oxidant streams.
- the process further comprises the step of feeding the conveying gas to a fuel feeder having a hopper containing the particulate fuel, the fuel feeder being adapted and configured to produce a flow of the particulate fuel
- 10 fluidized by the conveying gas towards the burner block, wherein the flow of particulate fuel and conveying gas towards the burner block from the fuel feeder is split into at least two flows of particulate fuel and conveying gas comprising said at least two streams of particulate fuel injected into the furnace.
- 15 - the flow from the feeder is split at a point upstream of the burner block.
- the flow from the feeder is split inside the burner block.

Brief Description of the Drawings

For a further understanding of the nature and objects of the present
20 invention, reference should be made to the following detailed description, taken in conjunction with the accompanying drawings, in which like elements are given the same or analogous reference numbers and wherein:

Figure 1 is a front elevation view of an embodiment of the inventive burner
25 block.

Figure 2 is a front elevation view of another embodiment of the inventive burner block.

Figure 3 is a schematic of the fuel and oxidant injections into the furnace.

Figure 4 is a first embodiment of a cross-sectional view of FIG 2 taken
30 along line A-A.

Figure 5 is a second embodiment of a cross-sectional view of FIG 2 taken along line A-A.

Description of Preferred Embodiments

According to the invention, a flat flame is achieved with injection of multiple streams of particulate fuel (particulate solid fuel fluidized with a conveying gas) above a first portion of primary oxidant injected into the furnace in the form of multiple high speed streams and below an injection of secondary oxidizer. Each fuel stream is injected into the furnace from a nozzle that is disposed within a fuel passageway. The fuel passageway is in the form of bore extending through the burner block that emerges from the burner block front face. The nozzle extends to a downstream end at a point in the bore that is upstream of the burner block front face to form a recess in between the burner block front face and the downstream end of the nozzle. Each nozzle is sized with a diameter to allow an annular space in between an inner surface of the bore and an outer surface of the nozzle. A second portion of primary oxidant is also injected into the furnace from the annular spaces to surround each of the fuel streams.

In addition to proposing a new mechanism for achieving a flat flame with particulate fuel, the invention solves a problem inherent in combustion of particulate fuels. In order to achieve satisfactory burnout of the fuel particles, the fuel stream velocity must not be too high. This is because the fuel particles need to be satisfactorily burnt before they impinge against a wall of the furnace. In contrast to rapidly-combusted natural gas or fuel oil, the relatively slower-combusting solid fuel particles require a relatively longer residence time for achieving satisfactory burnout. On the other hand, too low of a fuel stream velocity might cause the combustion zone and flame to rise due to buoyancy. Moreover, too low of a fuel stream velocity may cause fuel particles to accumulate in the fuel nozzle because the velocity of the conveying gas is not sufficient to fluidize the fuel particles.

By injecting the primary oxidant streams at high velocities, the combustion zone and flame may be prevented from rising due to buoyancy despite a relatively low fuel stream velocity. This is because the conveying gas and fuel particles become entrained to some degree in the high velocity primary oxidant stream. At the same time, the solid fuel particles are still allowed a sufficient residence time to satisfactorily burn out before impinging against the furnace wall. Thus, it may be said that injection of multiple streams of particulate fuel above or below multiple

streams of high velocity primary oxidant streams allows the achievement of a flat flame with a particulate fuel-fired burner.

The solid particulate fuel may be any pulverized solid particulate fuel whose average size is less than 300 μm . Typically, the fuel is coal or pet-coke.. The conveying gas may be air, recycled flue gas, or CO_2 (not recycled flue gas). The minimum amount and velocity of conveying gas necessary fluidize the particulate solid fuel (without incurring significant accumulation of particulate solid fuel in the burner block) is well known in the art of solid particulate fuel-fired burners. Each fuel stream injected into the furnace typically has a cylindrical cross-section and optionally has a swirl. The swirl acts as an additional flame stabilizer because it helps the fuel stream to be more quickly mixed with surrounding oxidant and its axial momentum is more rapidly dissipated into a lateral direction.

The recess plays two roles. First, the recess causes a reduction in the velocity of the fuel stream as it emerges from the downstream end of the nozzle to the desired exit velocity. This is important because, without such a recess, the velocity of the fuel stream could not be decreased below the minimum velocity that is necessary for satisfactory fluidization of the solid fuel particles by the conveying gas. The typical industrial standard is to have a conveying gas velocity of higher than about 15m/s. It is desirable to achieve a velocity lower than the minimum fluidization velocity because it allows the fuel particles to achieve burnout in a smaller space, such as the interior of an industrial melting furnace. At higher velocities, the fuel particles may impinge against a wall of the furnace before burnout. Second, the recess, a slight amount of mixing will occur between the fuel stream and the annulus of primary oxidant in between the burner block face and the downstream end of the nozzle. This slight premixing improves oxygen availability for ignition and also enhances flame stability.

The distance in between the burner block front face and the downstream end of the nozzle (i.e., the recess) may be as great as 2-10 cm (for example, 3 cm or 6 cm or 9 cm). The recess may have a constant cross-sectional dimension. In other words, it may have the shape of a cylinder with a constant diameter. Alternatively, the recess may taper outwardly. In this latter case, the bore forming the fuel passageway widens at the downstream end adjacent the burner block front face. The tapering may begin at the downstream end of the fuel nozzle or it

may begin at a point upstream of the downstream end of the fuel nozzle. An outwardly tapering recess is advantageous because it expands and slows down the fuel stream as it emerges from the fuel nozzle. This helps to achieve a fuel stream injection velocity that is sufficiently low to allow satisfactory burnout of the fuel particles before they impinge the furnace wall while also maintaining the minimum velocity sufficient for fluidization of the particulate fuel inside the fuel nozzle.

While each of the primary oxidant and secondary oxidant is typically industrially pure oxygen for safety reasons, it may include minor amounts of other gases. The specific purity of the industrially pure oxygen depends upon the method of production and whether or not the produced oxygen is further purified. For example, the industrially pure oxygen may be gaseous oxygen from an air separation unit that cryogenically separates air gases into predominantly oxygen and nitrogen streams in which case the gaseous oxygen has a concentration exceeding 99% vol/vol. The industrially pure oxygen may be produced through vaporization of liquid oxygen (which was liquefied from oxygen from an air separation unit, in which case it, too, has a purity exceeding 99% vol/vol. The industrially pure oxygen may be also be produced by a vacuum swing adsorption (VSA) unit in which case it typically has a purity of about 92-93% vol/vol. The industrially pure oxygen may be sourced from any other type of oxygen production technology used in the industrial gas business.

The high speed primary oxidant streams typically have cylindrical cross-sections. As discussed above, primary purpose of the high speed primary oxidant streams is to ensure the flatness of the flame by entraining the fuel particles from the fuel streams. The high speed primary oxidant streams also provide for partial combustion of the fuel in a first combustion zone. The role of the secondary oxidant stream(s) is to achieve full combustion of the solid particulate fuel while allowing staging of the combustion in order to reduce NO_x. This is accomplished by partitioning the total amount of oxidant necessary for combustion into two portions: one for the primary oxidant and one for the secondary oxidant. It may be said that the secondary oxidant stream(s) and the high speed primary oxidant streams envelop the flame streams to achieve full combustion thereof. The total amount of oxidant injected by the burner is allocated between first and second

portions of primary oxidant and secondary oxidant as follows: 20-40% first portion of primary oxidant (i.e., high speed primary oxidant streams); 50-70% secondary oxidant; and 5-10% second portion of primary oxidant (i.e., annulus of primary oxidant surrounding fuel stream).

5 The secondary oxidant stream(s) may be injected into the furnace at a downward angle Θ towards the flame. In case the velocities of the fuel streams and high speed primary oxidant streams lead to a lifted flame, injection of the secondary oxidant stream(s) at an angle Θ toward the flame enhances maintenance of the flat flame in a horizontal plane. The angle Θ is typically 4-10.
10 In one embodiment, it is 7.

Each of the streams of primary oxidant (whether high speed below the fuel streams or annular around the fuel streams), and/or each of the stream or streams of secondary oxidant may optionally be swirled. For fuels having a relatively lower volatile content, the mixing of the fuel with oxidant can be further enhanced by
15 employing a swirl (especially for the oxidant streams) of up to 40°.

The high speed primary oxidant stream has an axial velocity higher than that of the combined fuel stream and annular, second portion of primary oxidant. Typically, each high speed primary oxidant stream is injected into the furnace with an axial velocity of 10 m/s to 50 m/s while the typical axial velocity of the fuel
20 stream is no more than 6 m/s. The stream or streams of secondary oxidant typically has a velocity of about 20 m/s. While the second portion of the primary oxidant (i.e., the annulus of primary oxidant around the fuel stream) typically has a velocity of no more than 6 m/s, if a swirl is employed for that oxidant injection, its velocity may be as much as 10 m/s.

25 The burner block includes a plurality of bores forming primary oxidant passageways that emerge at the front face. It also includes a plurality of bores forming fuel passageways that similarly emerge at the front face. As described above, the fuel streams are injected from nozzles (such as metallic ones) that extend through the bores in the burner block forming the fuel passageways. Also
30 as described above, the nozzles are sized to allow annular spaces, each one of which is defined by the outer surface of the respective nozzle and the inner surface of the respective bore forming the fuel passageway. The burner block also includes at least one bore forming a secondary oxidant passageway.

Typically, the bores forming the fuel passageways extend all the way through the burner block from the rear face to the front face. The particulate fuel and conveying gas is fed to the fuel nozzles from a manifold that splits a single stream of particulate fuel fluidized with conveying gas into multiple streams.

5 Typically the manifold is upstream of the burner block. The single stream is formed by feeding the conveying gas to a fuel feeder having a hopper containing the particulate fuel. The fuel feeder is adapted and configured to produce a flow of the particulate fuel fluidized by the conveying gas towards the manifold. Such particulate fuel feeders are well known in the art. The manifold may alternatively
10 be positioned adjacent to the rear face of the burner block or even inside the burner block.

Typically, the bores forming the primary oxidant passageways and the secondary oxidant passageway(s) also extend all the way through the burner block from the rear face to the front face. Oxidant (defined above) is fed to the
15 primary oxidant passageways and secondary oxidant(s) from an oxidant source via an oxidant manifold. The manifold is typically disposed at the rear face of the burner block but may even be disposed within the burner block itself.

The burner block may have any number of fuel passageways (and fuel nozzles) so long as there are at least two and each emerges at the burner block
20 front face in a same horizontal plane. The burner block may similarly have any number of primary oxidant passageways (and fuel nozzles) so long as there are at least two and each emerges at the burner block front face in a same horizontal plane. While the burner block may have only a single secondary oxidant passage, if it contains two or more, each of them emerges at the front face of the burner
25 block in a same horizontal plane. One of ordinary skill in the art will recognize that a "same horizontal plane" means that the passageways in question emerge at the burner block front face at generally a same height from the bottom face of the burner block.

With the above description in mind, the primary oxidant passageways, fuel
30 passageways, and secondary oxidant passageways are staggered so that as one goes up from the bottom face of the burner block to the top face, the passageways are not oriented in a same vertical plane. Typically, the burner block includes two fuel passageways (with two fuel nozzles), three primary oxidant

passageways, and two secondary oxidant passageways. Alternatively, the burner block may have four fuel passageways (with four fuel nozzles), three primary oxidant passageways, and two secondary oxidant passageways.

When the flat flame is oriented parallel to a molten bath of glass or metal in an industrial melting furnace, it provides radiative heating over a relatively wide surface area.

The following steps describe the typical operation of the flat flame burner. The streams of primary oxidant and fuel are initiated. A flame may be ignited by heating the furnace interior to the auto-ignition temperature of the particulate fuel using an auxiliary heat source such as one or more natural gas burners. Once an initial flame is established, the remainder of the oxidizer is supplied as the secondary oxidant stream for completion of combustion downstream of the ignition region.

With reference to the **FIGS.**, certain aspects of the invention will now be described.

As best illustrated in **FIG 1**, the burner block **2** includes two fuel passages **1A, 1B**, three primary oxidant passageways **3A, 3B, 3C**, and two secondary oxidant passageways **5A, 5B**. The burner block of **FIG 2** is similar to that of **FIG 1**, except that instead of two fuel passageways **1A, 1B**, it now includes four fuel passageways **1A, 1B, 1C, 1D**.

As best shown in **FIG 3**, a plurality of fuel streams **4** are injected from the burner block above a plurality of high speed primary oxidant streams **6**. The fuel and primary oxidant are combusted in a first combustion zone **7**. One or more secondary oxidant streams **8** are injected downwardly along an axis **1A** at an angle Θ to horizontal **HA**. The secondary oxidant combusts with the incomplete products of combustion from the first combustion zone **7** at a second combustion zone **9**.

As best illustrated in **FIG 4**, a fuel stream **11** flows inside of a fuel nozzle **13**. An annular stream **15** of the second portion of primary oxidant flows in the annular space defined by the outer surface of the fuel nozzle **13** and the inner surface of the fuel passageway **17**. The fuel slightly premixes with the second portion of primary oxidant in the recess **19** before the fuel stream **11** and annular stream **15** are injected into the furnace from the front face of the burner block **2**. The fuel

passageway **17** of **FIG 5** is similar to that of **FIG 4**, except that it tapers outwardly at a tapered section **21** in between the downstream end of the fuel nozzle **13** and the front face of the burner block **2**.

Preferred processes and apparatus for practicing the present invention
5 have been described. It will be understood and readily apparent to the skilled
artisan that many changes and modifications may be made to the above-
described embodiments without departing from the spirit and the scope of the
present invention. The foregoing is illustrative only and that other embodiments of
the integrated processes and apparatus may be employed without departing from
10 the true scope of the invention defined in the following claims.

What is claimed is:

1. A process for producing a flat flame in an industrial melting furnace using a solid fuel, comprising the steps of:

5 injecting a first portion of primary oxidant into the furnace as two or more high speed primary oxidant streams from a front face of a burner block at a same height from a bottom face of the burner block;

injecting at least two streams of particulate fuel into the furnace from the burner block front face at a same height from the burner block bottom face above
10 the high speed primary oxidant streams, the stream of particulate fuel comprising particles of solid fuel fluidized with a conveying gas;

injecting a second portion of primary oxidant into the furnace in the form of two or more annuli each one of which surrounds a respective one of said fuel streams, wherein:

15 said burner block has at least two fuel passages from which said at least two streams of particulate fuel are injected into the furnace;

each of said fuel passages has a fuel nozzle extending through it to define annular passageways between inner surfaces of the fuel passages and outer surfaces of the fuel nozzles;

20 said second portion of primary oxidant is injected into the furnace from the annular passageways; and

the fuel nozzles terminate at a point upstream of the burner block front face such that each of the fuel streams flows out the terminal end of an associated fuel nozzle and mixes with the second portion of primary
25 oxidant in the fuel passageways prior to being injected into the furnace;

combusting said first and second portions of primary oxidant with said fuel streams in the furnace at a first combustion zone to produce a flat flame and incomplete products of combustion;

injecting secondary oxidant into the furnace as at least one secondary
30 oxidant stream from the burner block front face above said injection of fuel streams; and

combusting said secondary oxidant with said incomplete products of combustion at a second combustion zone.

2. The process of claim 1, wherein said secondary oxidant stream is injected downward at an angle toward the flat flame.

5 3. The process of claim 1 or 2, wherein said high speed primary oxidant streams are injected into the furnace at an axial velocity of 10 m/s to 50 m/s.

10 4. The process of claims any of claims 1-3, wherein said at least two fuel streams are injected into the furnace at an axial velocity of no more than 6 m/s.

15 5. The process of any of claims 1-4, wherein the second portion of primary oxidant is injected into the furnace with a swirl.

20 6. The process of any of claims 1-5, wherein the second portion of primary oxidant comprises 5-10% of a total amount of oxidant injected into the furnace by said first and second portions of primary oxidant and said secondary oxidant stream.

7. The process of any of claims 1-6, wherein the fuel stream is injected into the furnace with a swirl.

25 8. The process of any of claims 1-7, wherein each of said high speed primary oxidant streams is injected into the furnace with a swirl.

9. The process of any of claims 1-8, wherein the conveying gas is selected from the group consisting of air, CO₂, and flue gas.

30 10. The process of any of claims 1-9, wherein said at least two particulate fuel streams comprises two particulate fuel streams.

11. The process of any of claims 1-10, wherein said at least two particulate fuel streams comprises four particulate fuel streams.

5 12. The process of any of claims 1-11, wherein said at least two high speed primary oxidant streams comprises two primary oxidant streams.

13. The process of any of claims 1-12, wherein said at least one secondary oxidant stream comprises two secondary oxidant streams.

10 14. The process of any of claims 1-13, further comprising the step of feeding the conveying gas to a fuel feeder having a hopper containing the particulate fuel, the fuel feeder being adapted and configured to produce a flow of the particulate fuel fluidized by the conveying gas towards the burner block, wherein the flow of particulate fuel and conveying gas towards the burner block
15 from the fuel feeder is split into at least two flows of particulate fuel and conveying gas comprising said at least two streams of particulate fuel injected into the furnace.

20 15. The process of claim 14, wherein the flow from the feeder is split at a point upstream of the burner block.

16. The process of claim 14, wherein the flow from the feeder is split inside the burner block.

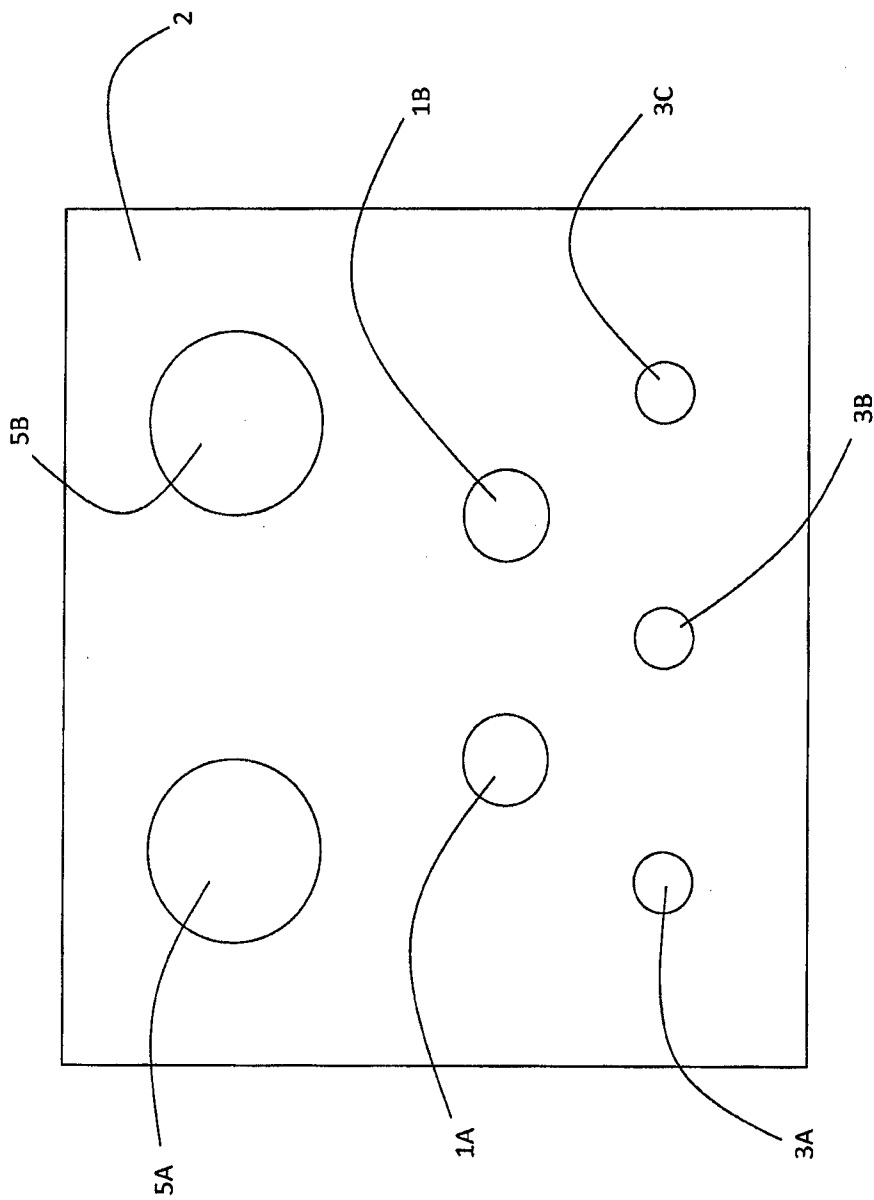


FIG 1

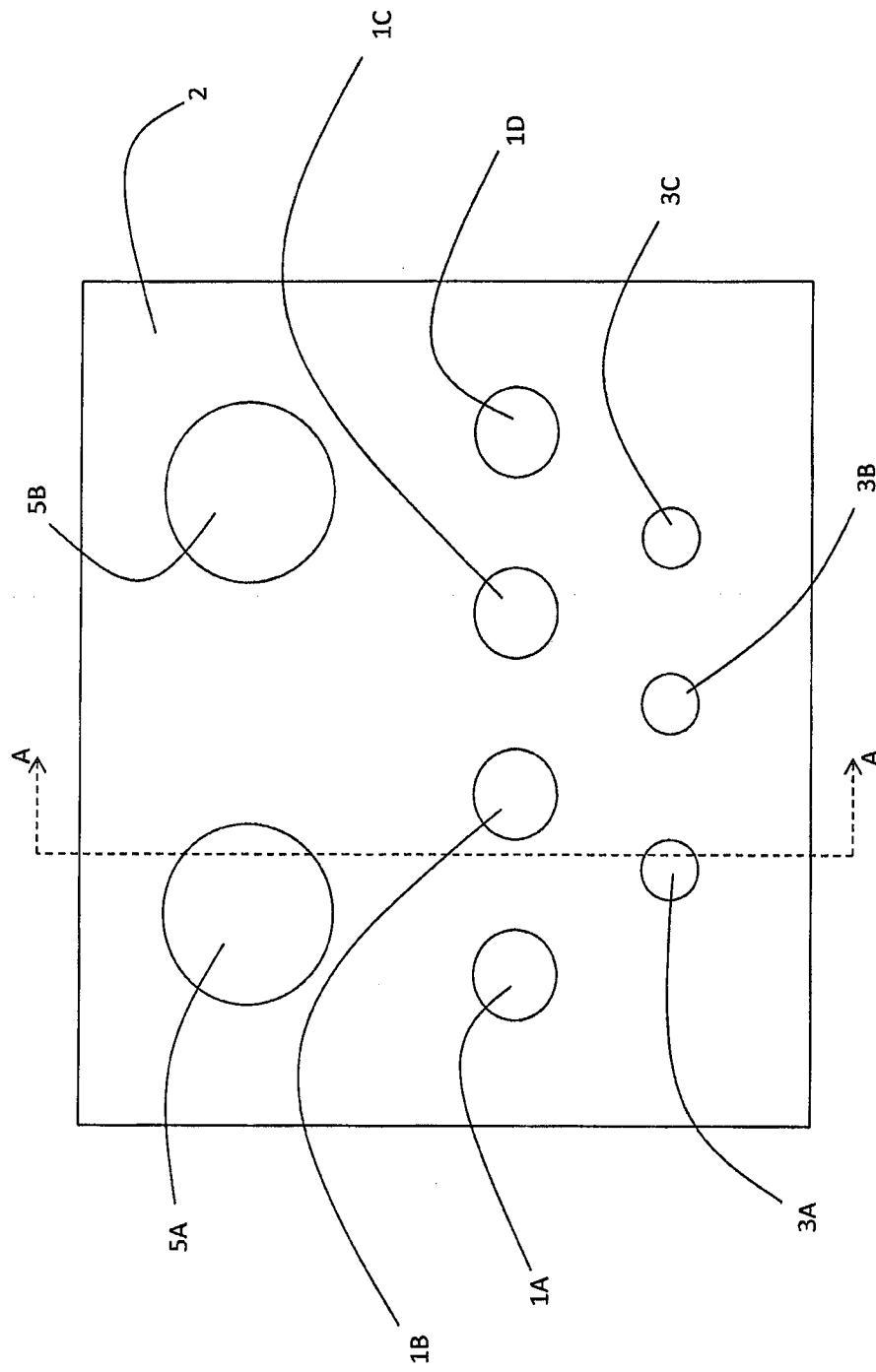


FIG 2

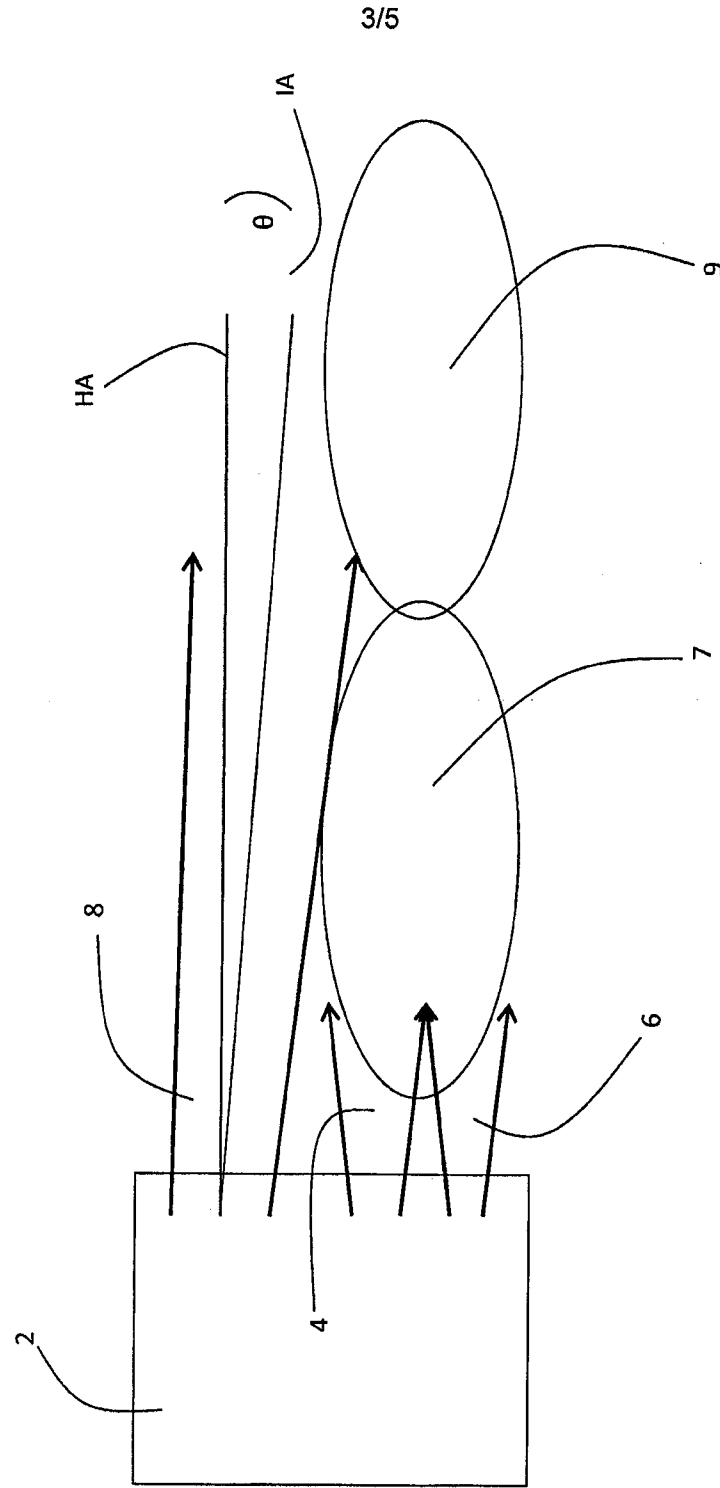


FIG 3

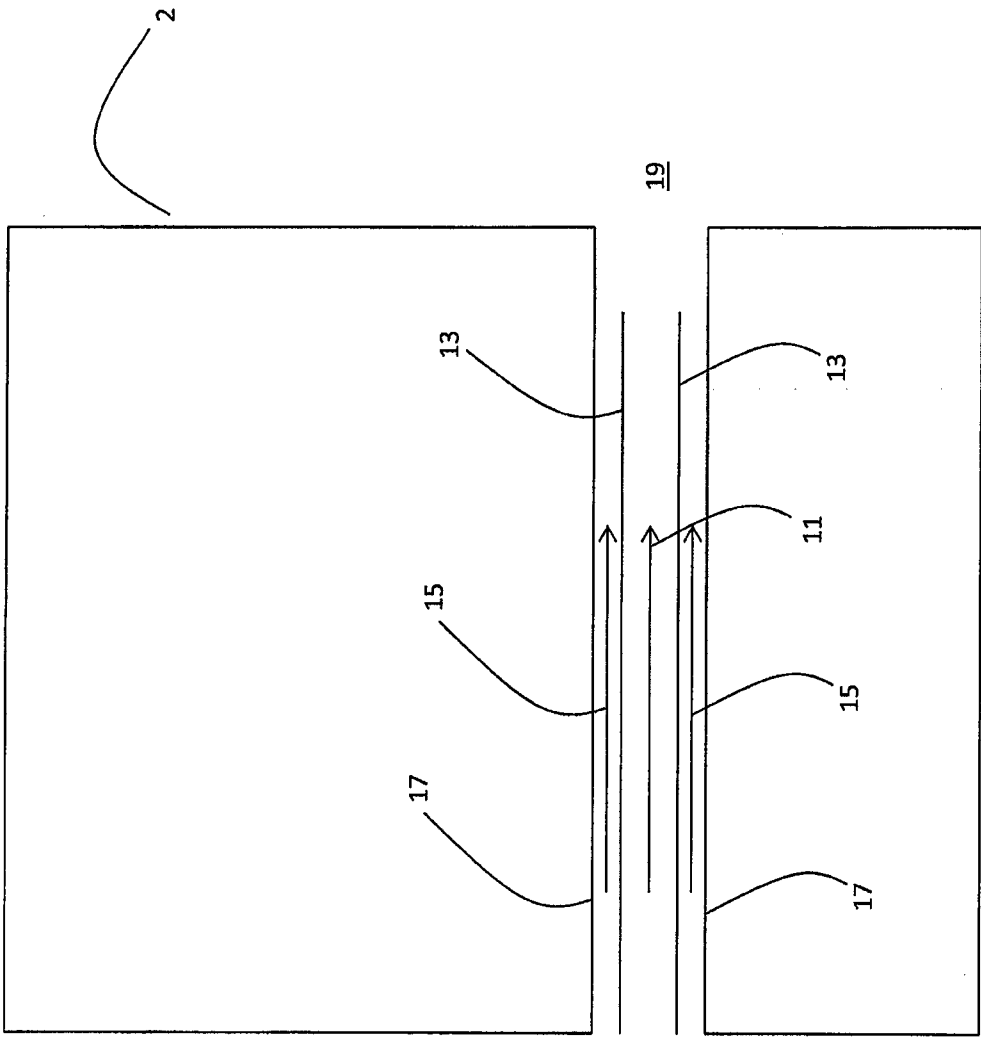


FIG 4

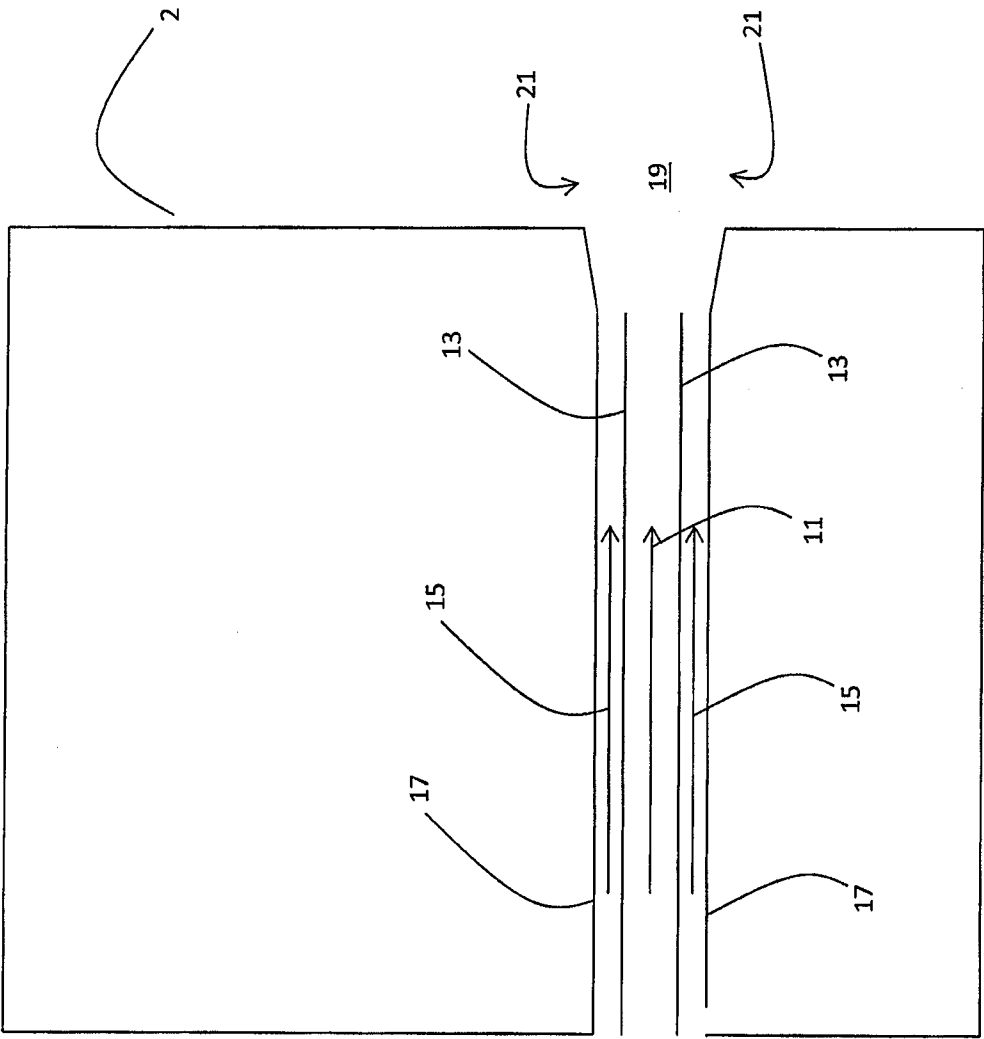


FIG 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2011/084988

A. CLASSIFICATION OF SUBJECT MATTER

See the extra sheet

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)

UPC: F23D, F23C5, C03B5

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

(EPODOC, WPI, CNPAT, CNKI: burner, flat, flame, NOx, solid, fuel, oxidant, fuel w oxygen, oxyfuel, nozzle, stage, incomplete, combustion

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category' *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP2202460A2 (MESSER AUSTRIA GMBH)30 Jun. 2010(30.06.2010) description paragraphs [0022]-[0030], figures 1-2	1-16
A	CN102138040A (APR LIQUIDE) 27 Jul. 2011(27.07.2011) the whole document	1-16
A	WO02081967A1 (APR LIQUIDE A DIRECT & CONSELL SURVELL et al.) 17 Oct. 2002(17.10.2002) the whole document	1-16
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A	US2003054301 A1 (APR LIQUIDE SA et al.)20 Mar. 2003(20.03 .2003) the whole document	1-16
A	US5554022A (XOTHERMIC INC)10 Sep. 1996(10.09.1996) the whole document	1-16

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 21 Sep. 2012(21 .09.2012)	Date of mailing of the international search report 25 Oct. 2012 (25.10.2012)
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 facsimile No. 86-10-62019451	Authorized officer CHANG Mengyuan Telephone No. (86-10)62084961

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN20 11/084988

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
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INTERNATIONAL SEARCH REPORT
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International application No.
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN20 11/084988

A. CLASSIFICATION OF SUBJECT MATTER

F23C5/14(2006.01)i

F23D1/00(2006.01)i