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(54) **Title:** A SYSTEM FOR BURNING PULVERIZED SOLID FUEL AND A METHOD THEREOF

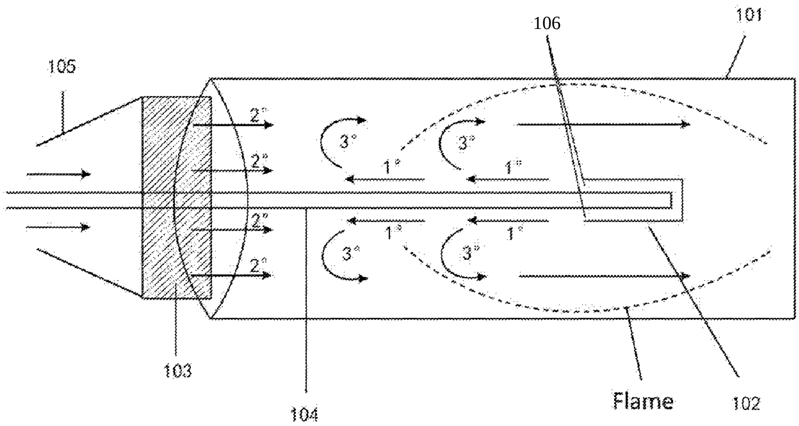

Fig. 1

(57) **Abstract: A** system for burning pulverized solid fuel and a method thereof are provided. The system comprises a combustor chamber (101), a blowpipe (104) introducing a mixture of pulverized solid fuel and a primary combustion air into the combustor chamber (101), a deflecting hood (102), and an opening (105) introducing a secondary combustion air (2°) into the combustor chamber (101). In the absence of the secondary combustion air (2°), the deflecting hood (102) forces the fuel and primary air mixture to reach the proximity of the opening for the introduction of the secondary combustion air (2°).

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A SYSTEM FOR BURNING PULVERIZED SOLID FUEL AND A METHOD THEREOF

TECHNICAL FIELD

The present invention relates to the field of combustors for small and medium sized combustors using pulverized solid fuel, and particularly a novel deflecting hood combustor design.

BACKGROUND

This invention is an improvement on the well known 'deflection hood' system fitted at the end of the transport air and pulverized solid fuel (thereafter referred as primary air/fuel mixture) blowpipe designed to run along the central axis of a combustor. The present invention also allows for a device that can allow for an adjustable rotational influence upon the secondary air.

The patent DE10232373B4 describes a system whereby a blowpipe that supplies the primary air/fuel mixture is made to run along the central axis of a combustor (whose design is a muffle burner linked to a flame acceleration nozzle at their largest diameters). The blowpipe's nozzle outlet is fitted along the axis of the combustor and a deflecting hood is placed in front of the nozzle of the blowpipe so as to redirect the stream of primary air/fuel mixture back towards the inlet of the muffle burner. Secondary air is supplied through a profiled blade cascade affixed at the inlet of the muffle burner. Consequently, the secondary air stream enters the combustor in a rotational manner (e.g. creating a 'vortex') whereby the secondary air stream runs largely along the walls of the combustor and away from its axis.

The method of DE10232373B4 is as follows, the secondary air stream supplied into the muffle burner initially goes through the profiled blade cascade which causes the stream to rotate intensely along the walls of the muffle burner in a vortex-like manner. At the same time, the primary air/fuel mixture stream is supplied through the blowpipe into the center of the combustor (at around the position of largest diameter of the muffle burner) and redirected the other way by the deflecting hood. This redirected stream moves along the axis of the chamber and at the same time experiences a powerful reflux effect caused by the secondary air moving opposite of it and running along the walls of the chamber in a vortex and thus creating a powerful pull of the primary air/fuel mixture. A primary flame settles where the primary air/fuel mixture exits the deflecting hood's annular passage and runs along the axis of the burner (roughly following the path of the primary air blowpipe). Given that the bulk of the combustion air moves along the walls of the chamber in a rotational manner, the axis of the chamber is a zone of relative oxygen depletion. In effect, this means that the primary flame cannot fully combust the fuel but instead preheats it before the fuel enters the powerful reflux running along the walls of the chamber. The main flame which allows for more complete combustion of the fuel settles along the walls (but not directly on it) and settles at around the zone which encompasses 75%-90% of the radius of the chamber.

Although DE10232373B4 describes a very efficient system for high load combustion of pulverized fuels, the very reflux dynamics that maximize the efficiency of combustion are detrimental whenever a low fuel load is used. This is largely due to combustion dynamics within the combustor at different fuel densities. At full or high loads, the pulverized fuel can easily disperse itself homogenously across the powerful rotational flow (or 'vortex') and achieve a stable flame through the constant stream of fuel. Unfortunately, whenever low fuel loads are used, the dispersal of fuel along the powerful rotational flow is much more problematic. The lower density of the fuel signifies an erratic stream of fuel and consequently, an unstable flame. In numerous combustion experiments we have conducted, the primary flame that formed the core claim of DE10232373B4 was rarely observed and extremely difficult to sustain. In fact, the inventor of DE10232373B4, Dr. Schoppe, pointed out the weakness of his system and mentions that the turndown ratio is around 40%. This is unsatisfactory result for any systems that require a high turndown value.

Therefore, our invention proposes an alternative design of the deflecting hood structure where the primary flame is neither formed nor required, and allows for both the flame stability and the turndown ratio to significantly be increased through a simple but effective new design.

SUMMARY OF INVENTION

The present invention allows a novel implementation of the deflecting hood combustor design, by creating a powerful primary air/fuel stream projected substantially in opposite direction of the secondary air stream, without having to rely at least partially on the pull effect created by the rotation of the secondary air stream. This is achieved by the elongation of the deflecting hood to protrude further back from the blowpipe's outlet so that the primary air/fuel exits the blowpipe with substantial directional momentum projected substantially against the flow of the secondary air. Consequently, the stream of primary air/fuel mixture blown into the combustor chamber is largely concentrated along the axis of the said combustor chamber, in a well formed stream, which effectively raises the local concentration of fuel in the airstream for a more stable flame.

In accordance with one embodiment of the present invention, the system includes a combustor chamber, a blowpipe that introduces a mixture of pulverized solid fuel and a primary combustion air into the combustor chamber in a first direction, a deflecting hood that is fitted at the outlet of the blowpipe and reverses the flow direction of the fuel and primary combustion air mixture, and an opening that introduces a secondary combustion air into the combustor chamber substantially along the first direction. In the absence of the secondary combustion air, the deflecting hood forces the fuel and primary air mixture to reach the proximity of the opening for the introduction of the secondary combustion air.

In accordance with one embodiment of the present invention, the deflecting hood has a tube of larger diameter than that of the blowpipe, and thus an annular passage 106 is formed for the outflow of the primary air/fuel mixture into the combustor chamber.

In accordance with one embodiment of the present invention, the system further includes a profiled grid cascade whose rotational influence on the secondary air is widely adjustable. Such adjustability allows for maximal or minimal pull exerted on the primary air/fuel stream, yielding more operational flexibility.

In accordance with one embodiment of the present invention, the method of the present invention can best be explained by the differences between the 'high or full fuel load' and 'low fuel load' scenarios.

When high or full fuel loads are required, the profiled blade cascade is adjusted so as to cause a strong rotational influence upon the stream of secondary air, thus, causing a powerful vortex within the combustor where the secondary air stream runs along the walls of the combustor and significantly away from its axis. Given that there is a relatively low proportion of secondary air running along the axis of the combustor, the primary air/fuel mixture air stream is unimpeded and runs far back towards the inlet of the combustor where it eventually mixes with the powerful vortex caused by the secondary air which runs along the walls of the combustor in a conical manner. Once the primary air/fuel mixture stream enters the secondary air vortex, then combustion of the fuel occurs in a highly efficient manner due to the fact that the fuel is made to properly mix inside a powerful reflux stream created by the inter dynamics of the vortex and the incoming primary air/fuel mixture stream.

Whenever a low fuel load must be used, the profiled blade cascade is adjusted so as to cause little or no rotational influence upon the stream of secondary air. Thus, secondary air is blown into the combustor and disperses itself in a fairly homogenous manner (i.e. the amount of air running along the walls and across the central axis is similar). The fuel load within the primary air/fuel mixture stream volume is lowered to the desired amount. In such a scenario, a reflux effect occurs mainly along the central axis of the chamber since the primary air/fuel mixture stream is projected at high velocity against the stream of secondary air. One will notice that this is unlike the previous 'high or full fuel load' scenario where the reflux is aided by the suction created by the rotating vortex of the secondary air, now that the central axis of the combustor is supplied with oxygen from the secondary air (which was not the case when the rotation of the secondary air stream is strong), combustion of the fuel largely occurs at the central axis. Furthermore, given that the primary air/fuel stream is projected from the prolonged deflecting hood's annular passage in a fairly straight line, the pulverized fuel is mainly concentrated within the axis of the combustor. Therefore, efficient combustion and a stable flame are effectively achieved at low fuel loads. From the inventor's own experience, the system can achieve a turndown ratio of around 20%; a major improvement upon the prior art.

This simplified system has two major advantages relative to the prior art in that it increases the turn down ratio to a relatively low value vis-a-vis prior art and the system is simple and comparatively easy to implement on new or existing devices.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional illustration of one of the embodiments of the present invention according to a low fuel load scenario.

Fig. 2 is a cross-sectional illustration of the one of the embodiments of the present invention according to the high to full fuel load scenario.

Fig. 3 is an illustration of the adjustable profile blade cascade for both high to full fuel load and low fuel load scenarios.

Fig. 4 is a cross-sectional illustration of the deflecting hood with the relevant flow dynamics explained.

DETAILED DESCRIPTION OF THE INVENTION

The present invention may be better understood and its many objects and advantages will become apparent to those skilled in the art by reference to the accompanying drawings.

Fig. 1 is a cross-sectional illustration of one of the embodiments of the present invention. The combustor chamber 101 is fitted with a blowpipe 104 that runs along the axis of the combustor chamber 101 and supplies a mixture of pulverized solid fuel and a primary combustion air into the chamber. At the outlet of the blowpipe 104 is an elongated deflecting hood 102 that protrudes far back along the axis of the blowpipe 104. An opening 105 is fitted at the inlet of the combustor chamber 101 so as to supply the secondary combustion air into the combustor chamber 101. An adjustable profile blade cascade 103 is fitted in between the opening 105 and the combustor chamber 101 so as to adjust for strong, weak, or no rotational effect upon the secondary combustion air.

The method of the present invention can best be described by differentiating between two scenarios: low fuel load and high to full fuel load.

1. Low Fuel Load Scenario

Refer to Fig. 1 to see an embodiment of the present invention during a low load scenario. A primary air/fuel mixture is blown into the combustor chamber 101 through the blowpipe 104. Once the primary air/fuel mixture exits the blowpipe's outlet, it is forced by the deflecting hood 102 in a significantly opposite direction. The primary air/fuel mixture exits the deflecting hood 102 at its annular passage 106. The direction of the redirected primary air/fuel mixture stream is depicted by the arrows labeled 1°. An opening 105 projects the secondary air into the combustor chamber 101. Prior to entering the chamber the secondary air goes through an adjustable profiled blade cascade 103. Because the deflecting hood 102 has a tube of larger diameter than that of the blowpipe 104, an annular passage 106 is formed for the outflow of the primary air/fuel mixture into the combustor chamber 101, and the length of the tube is around three times the difference between the diameters of the deflecting hood 102 and the blowpipe 104. Once the primary air/fuel mixture exits the annular passage 106 into the combustor chamber 101, is introduced into the stream of secondary air 2° that moves in a substantially opposite direction than that of 1°. This causes a reflux stream 3° whereby the primary air/fuel mixture mixes with the secondary air. In the absence of the secondary combustion air, however, the primary air/fuel mixture could reach the proximity of the opening 105 for the introduction of the secondary combustion air.

As mentioned beforehand, whenever a low fuel load is used, the profiled blade cascade 103 is adjusted so as to cause little or no rotational influence upon the stream of secondary air. Fig. 3 graphically depicts the adjustable profiled blade cascade 301-A adjusted to cause little or no rotational influence upon the secondary air stream as well as the adjustable profiled grid cascade 301-B adjusted so that there is a rotational influence upon the secondary air stream. Increasing or decreasing the strength of the rotational influence is achieved by adjusting the angle of the blades relative to the secondary air stream. At 90 degrees to the air direction, the air flow is effectively shut off. At near 90 degrees, the strongest rotational influence possible is achieved. Finally, at near zero degrees, no or little rational influence is achieved upon the flow of secondary air.

Referring back to Fig. 1, in the low fuel load scenario, the secondary air 2° is blown into the combustor chamber 101 and disperses itself in a fairly homogenous manner (i.e. the amount of air running along the walls and across the central axis is similar). The fuel within the primary air/fuel mixture stream 1° is lowered to the desired amount (as well as the secondary air 2° so as to avoid over- or under-supply of combustion air). In such a scenario, a reflux effect 3° occurs mainly within the central axis of the combustor chamber since the primary air/fuel mixture stream 1° is projected at high velocity against the stream of secondary air 2. Since the central axis of the combustor chamber 101 is supplied with oxygen from the secondary air 2°, combustion of the fuel largely occurs along the central axis. Furthermore, given that the primary air/fuel stream 1° is projected from the elongated deflecting hood 102's annular passage 106 in a fairly straight line, the pulverized fuel is mainly concentrated within the axis of the chamber. Therefore, efficient combustion and a stable flame along the axis of the combustor chamber are effectively achieved at low fuel loads.

2. High to Full Load Scenario

Refer to Fig. 2 to see an embodiment of the present invention during a high to full load scenario. Similar to the low fuel load scenario, the primary air/fuel mixture is blown into the combustor chamber 201 through the blowpipe 204. Once the primary air/fuel mixture exits the blowpipe 204's outlet, it is redirected by the deflecting hood 202 in a significantly opposite direction. The primary air/fuel mixture exits the deflecting hood 202 at its annular passage 206. The direction of the redirected primary air/fuel mixture stream is depicted by the arrows labeled 4°. An opening 205 projects the secondary air into the combustor chamber 201. Prior to entering the combustor chamber the secondary air goes through an adjustable profiled blade cascade 203. Once the primary air/fuel mixture exits the annular passage 206 into the combustor chamber 201, it is introduced into the stream of secondary air 5° that moves in a substantially opposite direction than that of 4°. This causes a reflux stream 6° whereby the primary air/fuel mixture mixes with the secondary air.

As mentioned previously, whenever a high or full fuel load is used, the profiled blade cascade 203 is adjusted so as to the maximum rotational influence upon the stream of secondary air. Fig. 3 graphically depicts the adjustable profiled blade cascade 301-B adjusted to cause a high rotational influence upon the secondary air stream.

When high or full fuel loads are required, the profiled blade cascade 203 is adjusted so as to cause a strong rotational influence upon the stream of secondary air, thus, causing a powerful vortex within the combustor chamber 201 where the secondary air 5° runs along the walls of the chamber and significantly away from its axis. Given that there is a relatively low proportion of secondary air 5° running along the axis of the combustor chamber, the primary air/fuel mixture air stream 4° is unimpeded and runs far back towards the inlet of the combustor chamber where it eventually mixes with the powerful vortex caused by the secondary air 5° and that runs along the walls of the combustor chamber in a conical manner. Once the primary air/fuel mixture stream 4° enters the secondary air 5° vortex, a reflux 6° is formed where the combustion of the fuel occurs in a highly efficient manner. This is due to the fact that the fuel is made to properly mixture inside the powerful reflux stream 6° that is created by the inter dynamics of the vortex and the incoming primary air/fuel mixture stream.

Dynamics of the Deflecting Hood

Fig. 4 is a cross-sectional illustration of the deflecting hood with the relevant flow dynamics explained. Taking a closer look at the deflecting hood 401 and the outlet of the primary air/fuel mixture blowpipe's 402 outlet can help one further understand the dynamics of the present invention. The primary air/fuel mixture stream 1° is blown out of the blowpipe 402 and comes into contact with the deflecting hood 401. Given the restricted space at that point, the primary air/fuel mixture stream 2° reverses its direction towards the annular passage 403 between the blowpipe 402 and the deflecting hood 401. From the inventor's own trial and error experimentation, it was established in order to ensure that the stream of primary air/fuel mixture is blown in a fairly straight direction, the design of the deflecting hood 401 should allow for the length B of the deflecting hood 401 to be around three times as long as the annular space which is two times length A. Allowing for such a design will ensure that the deflecting hood 401 stretches along a relatively long distance back along the blowpipe 402 and that the bulk of the volume the primary air/fuel mixture stream will continue in a direct path down the axis of the combustor chamber along the blowpipe 402 as it exits the annular passage 403 as is depicted with stream 3°. This design means that only a relatively small proportion of the stream 4° diverges out of that path.

The advantages of the present invention are explained as follows.

Referring back to Fig. 1, the stream 1° has a high velocity ranging from 15 to 25 m/s and its direction runs relatively central to the axis of the combustor chamber 101. Unlike the prior art, this effectively reduces or even eliminates the need for the pull generated by the strong rotation of the secondary air. As a result of this effect, and unlike the prior art, the system requires a relatively lower amount of secondary and primary air in order to generate a reflux. Therefore the invention allows for the generation of a stable flame and a better turndown ratio using a small amount of air and pulverized solid fuel. This is particularly important during low fuel loads since the high velocity primary air/fuel stream runs along the central axis of the combustor chamber 101 in a fairly straight line with the fuel/air denser towards the axis than that of its periphery. Thus, a powerful reflux stream is created along the axis where the fuel is most concentrated which can easily be ignited.

Therefore the present invention allows for the generation of a stable flame and a better turndown ratio using a small amount of air and pulverized solid fuel.

CLAIMS

1. A system for burning pulverized solid fuel, comprising:

- a combustor chamber;

- a blowpipe that introduces a mixture of pulverized solid fuel and a primary combustion air into the combustor chamber in a first direction;

- a deflecting hood that is fitted at the outlet of the blowpipe and reverses the flow direction of the fuel and primary combustion air mixture;

- an opening that introduces a secondary combustion air into the combustor chamber substantially along the first direction;

wherein, in the absence of the secondary combustion air, the deflecting hood forces the fuel and primary air mixture to reach the proximity of the opening for the introduction of the secondary combustion air.

2. The system in claim 1, wherein the deflecting hood comprises a tube of larger diameter than that of the blowpipe, forming an annular passage for the outflow of the mixture of the fuel and the primary combustion air into the combustor chamber, and wherein the length of the tube is around three times the difference between the diameters of the deflecting hood and the blowpipe.

3. A method for burning pulverized solid fuel, comprising:

- introducing a mixture of pulverized solid fuel and a primary combustion air into a combustor chamber in a first direction by a blowpipe;

- introducing a secondary combustion air into the combustor chamber substantially along the first direction through an opening of the combustor chamber;

- reversing the flow direction of the fuel and primary combustion air mixture by a deflecting hood that is fitted at the outlet of the blowpipe, wherein, in the absence of the secondary combustion air, the deflecting hood forces the fuel and primary air mixture to reach the proximity of the opening for the introduction of the secondary combustion air.

4. The method in claim 3, wherein the deflecting hood comprises a tube of larger diameter than that of the blowpipe, forming an annular passage for the outflow of the mixture of the fuel and the primary combustion air into the combustor chamber, and

wherein the length of the tube is around three times the difference between the diameters of the deflecting hood and the blowpipe.

Fig. 1

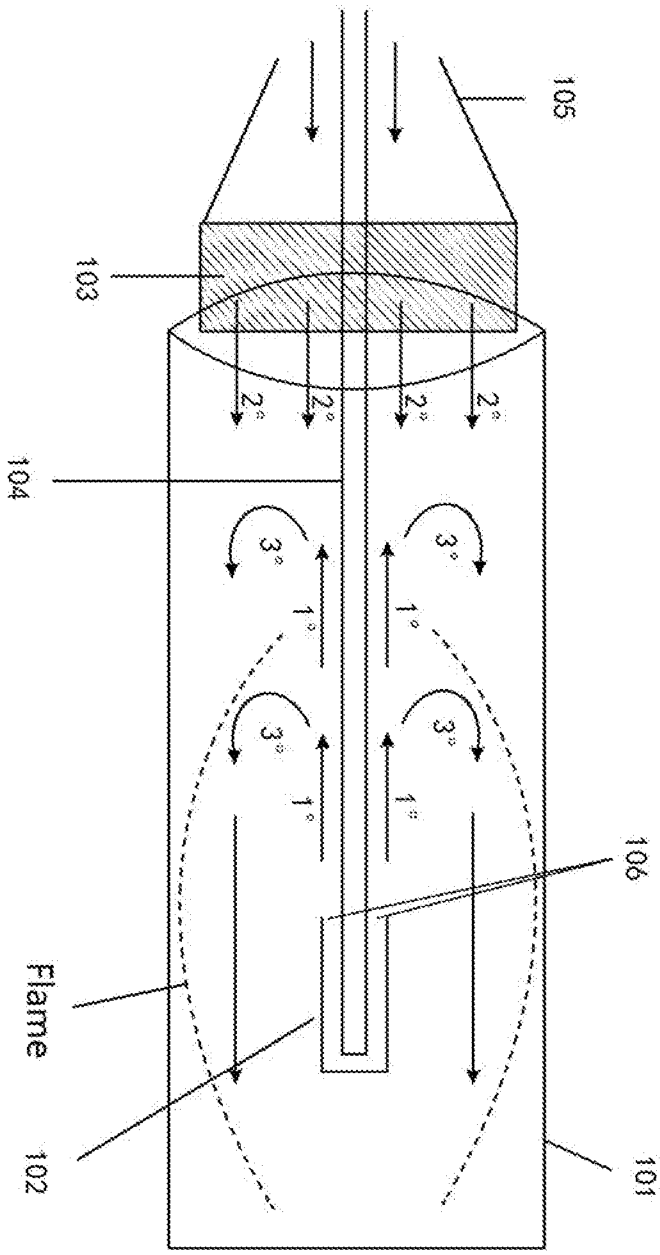


Fig. 2

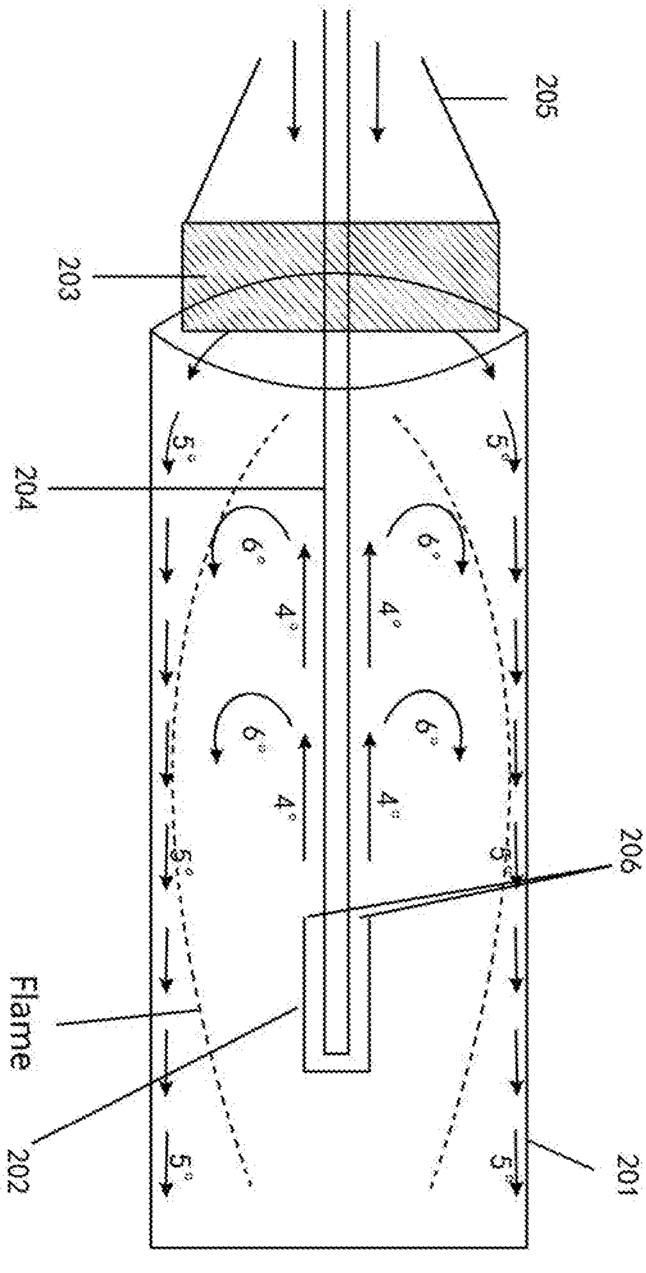
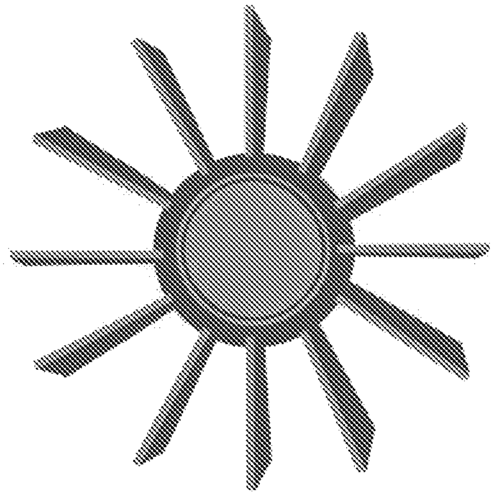
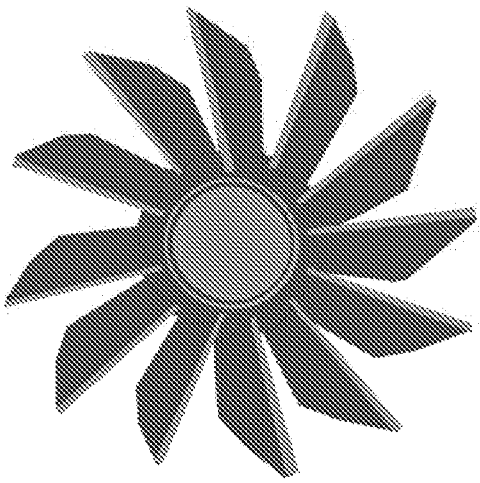


Fig. 3

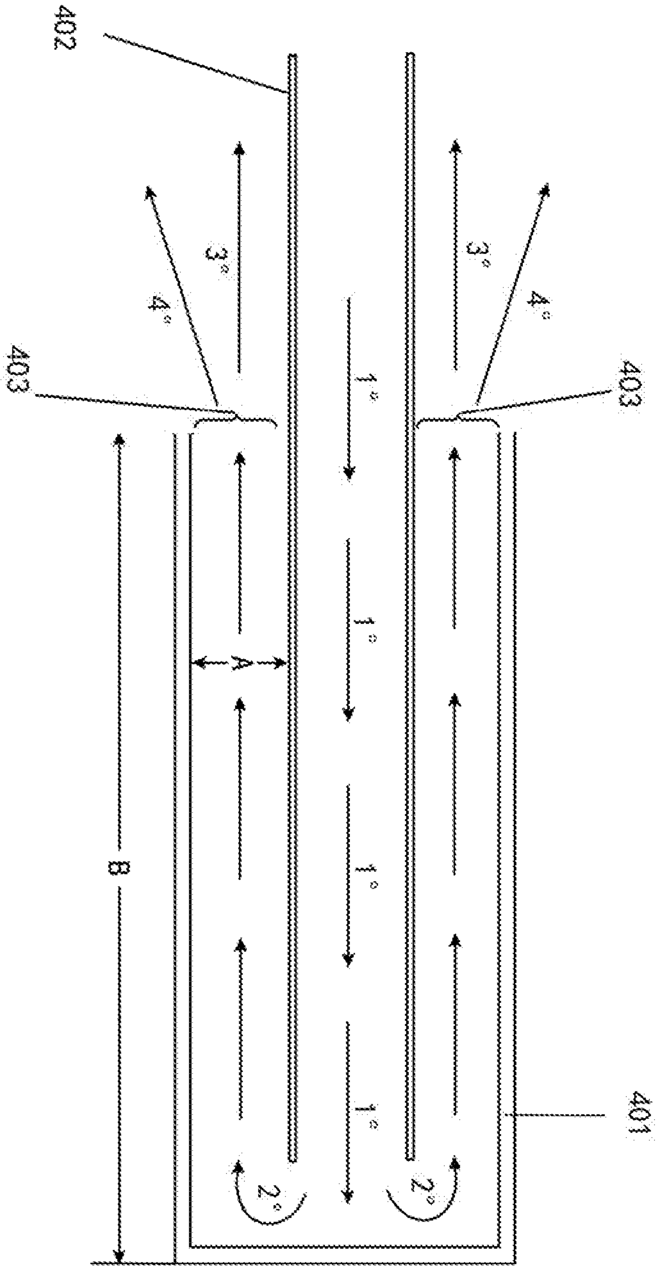


301–A



301–B

Fig. 4



INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

F23D l/00(2006.01)i; F23C 5/00(2006.01)i

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)

F23D, F23C

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, combustor, secondary, air, deflect+, revers+, hood, cap

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5317979 A (SCHOPPE F) 07 June 1994 (1994-06-07) description, line 49 to line 105, and figures 1-2	1-4
X	FR 2842584 Al (SCHOPPE F) 23 January 2004 (2004-01-23) abstract, and figures 1-2	1-4
X	CN 103791494 A (CHINA COAL RES INST) 14 May 2014 (2014-05-14) description, paragraphs [0014]-[0025], and figure 1	1-4
X	CN 101576255 A (CHINA COAL RES INST) 11 November 2009 (2009-1 1-1 1) description, page 2 paragraph 6 to page 3 paragraph 4, and figure 1	1-4
A	US 4057021 A (SCHOPPE F) 08 November 1977 (1977-11-08) the whole document	1-4

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

* Special categories of cited documents:

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"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

"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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 January 2016	**02 February 2016**

Name and mailing address of the ISA/CN	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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