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(54) COMBUSTION CHAMBER WITH AIR INJECTION SYSTEMS

BRENNKAMMER MIT LUFTEINBLASUNGSSYSTEMEN

CHAMBRE DE COMBUSTION AVEC SYSTÈMES D'INJECTION D'AIR

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Description

Field of the invention

[0001] The present invention relates to air injection systems for combustion chambers, particularly to secondary air injection systems for achieving multi-stage combustion of fuel.

Background to the invention

[0002] In the operation of thermal fired power stations, it is desirable to reduce NOx emissions as much as possible, while achieving high levels of fuel combustion to promote efficiency. These two aims are generally difficult to achieve in the same system, since high levels of fuel combustion require the supply of high levels of air in relation to the amount of fuel to be combusted. However, a high ratio of air to fuel tends to promote NOx formation.

[0003] It is known to operate thermal fired power stations according to a system of staged combustion. This system is based on the knowledge that NOx forms most readily at high temperatures. Thus, to limit NOx formation, fuel is initially burned in a sub-stoichiometric atmosphere (i.e. the air supplied is insufficient for complete fuel combustion), while subsequently being exposed to a further air stream, to help complete the combustion process.

[0004] Previously, this staged combustion has been achieved through the introduction of over-fire air (OFA) into the combustion system. In this arrangement, fuel and air are mixed to create a fireball in the combustion zone of a combustion chamber. A further air stream is introduced above the fireball, to promote oxidation of incompletely combusted fuel as it rises above the combustion zone and travels towards the furnace exit and flue gas duct.

[0005] EP1435485A describes a combustion system according to the preamble of claim 1.

Summary of the invention

[0006] Surprisingly, it has been found that the introduction of one or more secondary airstreams below the combustion zone (under-fire air) may provide a simpler and/or more effective way for reducing NOx emissions and/or increasing combustion levels.

[0007] In particular, it has been found that the injection of air along the axis of rotation of a combustion zone fireball may provide an effective means for increasing combustion levels of fuel at the centre of the fireball. This arrangement may allow the airstream to penetrate the fireball relatively easily, without the need to provide additional equipment, such as fans, to increase the pressure and/or velocity of the airstream. This method may be termed Separated Under-Fire Air injection.

[0008] Additionally, it has been found that the creation of an airstream that swirls around the axis of rotation of the fireball in a position below the combustion zone may

assist in maintaining stable rotation of the fireball and/or the centralisation of the fireball in the furnace, even in systems where relatively low amounts of air are supplied directly to the fireball. Thus, it may be possible to reduce the amounts of air supplied directly to the fireball (and hence reduce the levels of NOx emissions) while maintaining stable rotation of the fireball.

[0009] In addition, the presence of this airstream may help to oxidise incompletely combusted fuel from the fireball. Such an airstream may be termed Rotational Under-Fire Air.

[0010] In a first aspect, the present invention may provide a combustion system according to claim 1.

[0011] The secondary gas and/or air nozzle may be termed a Separated Under-Fire Air nozzle.

[0012] Typically, the secondary gas and/or air nozzle is provided in the base of the combustion chamber.

[0013] Typically, the flue gas duct is located above the combustion chamber, thus allowing combustion products to rise from the combustion zone and exit the combustion chamber via the flue gas duct. Typically, the flue gas duct is arranged to convey combustion products to one or more heat exchangers, as is known in the art.

[0014] Typically, the enclosing wall has a plurality of sub-sections that may be arranged to provide e.g. a rectangular cross-section.

[0015] The combustion devices generally comprise a plurality of burner nozzles and associated air nozzles. The burner nozzles are configured to supply fuel to the combustion chamber and are also provided with ignition means for igniting the fuel, while the associated air nozzles are configured to supply an airstream to the combustion chamber, for use in an initial combustion stage of the fuel and for imparting rotational momentum to the fireball. Such combustion devices are known in the art.

[0016] The secondary gas nozzle allows gas (this is typically air, but may include e.g. chemical agents for the reduction of SOx and/or NOx compounds, or even flue gas) to be directed through the centre of the fireball, along its axis of rotation, so as to promote more complete combustion of fuel at the centre of the fireball.

[0017] In previously-known systems, it has been attempted to achieve this effect through the use of an over-fire air system that directs air through the sides of the fireball above the main combustion zone e.g. above the fuel injectors and before the furnace exit and flue gas duct. However, these previous systems typically require additional pressure to be imparted to the over-fire air in order to penetrate the fireball, and thus additional fans and specially-configured ductwork may be needed to achieve this effect.

[0018] Advantageously, the present invention does not generally require the replacement of existing fans and/or ductwork. The system may be arranged to supply gas to the combustion devices and the secondary gas nozzle from the same source. Additionally, the gas supplied to the combustion devices and the secondary gas nozzle may be pressurised by the same fan.

[0019] In general, the base of the combustion chamber tapers in a direction away from the flue gas duct.

[0020] For example, the base of the combustion chamber may comprise two panels that are inclined towards each other in a direction away from the flue gas duct. The base generally also comprises two side walls that are aligned with each other. In this case, the base effectively has the shape of a hopper.

[0021] Typically, the two panels are inclined towards each other at an angle less than 60°, preferably less than 55°. In general, the two panels are inclined towards each other at an angle greater than 30°.

In general, the two panels do not meet, and so an aperture is provided between them that allows e.g. ash to be deposited from the combustion chamber into an ash box.

[0022] In certain embodiments, the secondary gas nozzle is provided in one of the two panels, and a further secondary gas nozzle is provided in the other of the two panels, the nozzle and further nozzle being typically in opposing positions.

[0023] In such embodiments, the distance between the nozzle and the upstream extremity of the base is generally less than 3 metres, preferably less than 2.5m, more preferably less than 2.2m. In general, the distance between the nozzle and the upstream extremity of the base is greater than 0.3m, more preferably greater than 0.5m.

[0024] The distance between the secondary nozzle and the combustion devices is generally about 10m, measured along the axis extending between the base and the flue gas duct, but this may vary depending e.g. on the overall size of the combustion system.

[0025] In other embodiments, the secondary nozzles may be configured to direct air and/or gas through the aperture that may be provided between the two panels of the base of the combustion chamber. The secondary nozzles may be located wholly outside the combustion chamber (e.g. beneath the combustion chamber) or may extend through the aperture.

[0026] The combustion system may also include nozzles for the injection of over-fire air, as is known in the art.

[0027] In a second aspect, the present invention may provide a method of operating a combustion system according to the first aspect of the invention, comprising the step of delivering fuel and gas into the combustion chamber by means of the combustion devices to generate a fireball having a stoichiometry less than 0.9, preferably less than 0.8, more preferably less than 0.7.

[0028] This fireball stoichiometry compares favourably with that of standard over-fire air systems, which is about 0.85-0.9 or 0.85-1.0.

[0029] Typically, the stoichiometry of the fireball is greater than 0.6.

[0030] The gas is typically air, but may include e.g. chemical agents for the reduction of SO_x and/or NO_x compounds and/or flue gas. As is known in the art, the stoichiometry of the fireball is defined as the ratio of the oxygen present in the fireball relative to the amount of oxygen required for complete combustion of the fuel

present in the fireball. Oxygen originating from secondary air sources (e.g. over-fire or under-fire air) or from leakage into the furnace is not taken into account in the calculation of fireball stoichiometry.

[0031] In a third aspect, the present invention may provide a method of operating a combustion system according to the first aspect of the invention, comprising the step of delivering gas into the combustion chamber via the secondary gas nozzle at a velocity between 40m/s and 70 m/s, preferably below 60 m/s.

[0032] Such velocities tend to be lower than those required for boosted over-fire air to penetrate the sides of the fireball.

[0033] Typically, the velocity of the gas injected via the secondary gas nozzle is greater than 40 m/s, preferably greater than 50 m/s.

[0034] In general, the pressure of the gas injected by the secondary gas nozzle is around 5-25 mbar above atmospheric pressure.

[0035] The combustion system used in the method of the second and third aspects of the invention may have one or more of the optional features of the combustion system of the first aspect of the invention.

[0036] The combustion system according to the first aspect of the invention may also have the following features.

[0037] The plurality of secondary gas nozzles may be termed Rotational Under-Fire Air nozzles.

[0038] The plurality of secondary gas nozzles typically injects air into the combustion chamber in a direction tangential to an imaginary circle located around the axis connecting the base and the flue gas duct (in general, this corresponds to the longitudinal axis of the combustion chamber). The imaginary circle may have a diameter of about 1.2m, although this will depend on the overall size of the combustion system.

[0039] This configuration causes a secondary airstream to swirl about the axis. The combustion devices and secondary gas nozzles are oriented such that the direction of rotation of the secondary airstream is the same as for the fireball. Thus, the secondary airstream helps to maintain stable rotation of the fireball, even in situations where low levels of gas are injected by the combustion devices into the fireball. As a result, it is possible to maintain a low stoichiometry in the fireball, so as to limit formation of NO_x under the high temperatures present in the fireball.

[0040] In general, the distance between the plurality of secondary gas nozzles and the combustion devices, measured along the axis connecting the base and the flue gas duct, is greater than 0.5m, preferably greater than 1m. Typically, this distance is less than 3m, preferably less than 2m.

[0041] In general, the system is arranged to supply gas to the combustion devices and the secondary gas nozzles from the same source. In certain cases, the gas supplied to the combustion devices and the secondary gas nozzles is pressurised by the same fan. This generally

allows the combustion system to be built more cheaply and efficiently.

[0042] In a fourth aspect, the present invention may provide a method of operating a combustion system according to the first aspect of the invention, comprising the step of delivering gas into the combustion chamber via the plurality of secondary gas nozzles at a velocity of 40-70 m/s.

[0043] The gas is typically air, but may include e.g. chemical agents for the reduction of SO_x and/or NO_x compounds.

Detailed description

[0044] The invention will now be described by way of example with reference to the following Figures in which:

Figure 1 shows a schematic perspective view of a first embodiment of a combustion system according to the first aspect of the invention, wherein the front face of the combustion system is not shown and certain faces of the combustion chamber are rendered transparent in order to reveal interior detail.

Figure 2 shows a detail view of a portion of Figure 1. A scaled-down version of Figure 1 indicates the location of the portion of Figure 2.

Figure 3 shows a detail view of a portion of Figure 1. A scaled-down version of Figure 1 indicates the location of the portion of Figure 3.

Figure 4 shows a perspective view of a twin chambered combustion system, based on the combustion system of Figure 1 and showing external ducts.

Figure 5 shows another perspective view of the twin chambered combustion system of Figure 4.

Figure 6 shows a schematic perspective view of the combustion system of Figure 1, when in use.

Figure 7 shows a plan view of the combustion system of Figure 1, showing air flow from Rotational Under-Fire Air inlets.

Figure 8 shows a schematic perspective view of a portion of a combustion system according to a second embodiment of the first aspect of the invention, wherein the front face of the combustion system is not shown.

Figure 9 shows a detail view of a portion of Figure 8.

[0045] Referring to Figure 1, a combustion system 10 has a combustion chamber 12 and a flue gas duct 14. In use, the flue gas duct is above the combustion chamber.

[0046] The combustion chamber has a base 16 having

two sides 16a,b that tend towards each other in a direction away from the flue gas duct 14. Thus, effectively, the base is shaped as a hopper having two sides that are aligned and two sides that are oriented towards each other. In this embodiment, the two sides 16a,b of the base 16 are oriented at 52° to each other.

[0047] The combustion chamber further has an enclosing wall 18 connecting the base 16 to the flue gas duct 14. The wall comprises four panels that are arranged to provide a rectangular cross-section.

[0048] Combustion devices 20 are arranged at the four corners of the enclosing wall 18. The devices include burner nozzles that are arranged to supply fuel to the combustion chamber and associated air nozzles that are arranged to supply an airstream to the combustion chamber.

[0049] The burner nozzles further include ignition means for igniting the fuel. The burner nozzles and associated air nozzles are oriented so that the fuel / air injected into the combustion chamber follows a rotational path around the longitudinal axis of the combustion chamber. The combustion devices 20 between them define a combustion zone or burner belt 22 within the combustion chamber.

[0050] Over-fire air nozzles 24 are provided between the combustion zone 22 and the flue gas duct 14, as is known in the art.

[0051] Referring to Figure 2, Rotational Under-Fire Air nozzles are provided on the enclosing wall 18, between the base 16 and the combustion devices 20. The Rotational Under-Fire Air nozzles are closer to the base 16 than to the combustion devices 20, and are typically 1-2m below the combustion devices.

[0052] Four Rotational Under-Fire Air nozzles are provided in this embodiment, each nozzle being adjacent to a respective corner of the enclosing wall. The Rotational Under-Fire Air nozzles 26 are arranged to supply a secondary airstream into the combustion chamber along a path that is tangential to an imaginary circle centred on the longitudinal axis of the combustion chamber. The direction of flow around the imaginary circle is the same as for the air and fuel supplied by the combustion devices 20. The imaginary circle, in this embodiment, has a diameter of about 1.2m.

[0053] Referring to Figure 3, Separated Under-Fire Air nozzles 28 are provided on the inclined sides 16a,b of the base 16. The nozzles are arranged to supply a further secondary airstream into the combustion chamber along the axial direction of the chamber.

[0054] The Separated Under-Fire Air nozzles are positioned, in this embodiment, at 0.5-2m from the lowest part of the base 16. The distance between the Secondary Under-Fire Air nozzles in this embodiment and the combustion devices 20 is about 10m.

[0055] Referring to Figures 4 and 5, external ducts 20a, 26a and 28a supply the air nozzles of the combustion devices 20, the Rotational Under-Fire Air nozzles 26 and the Separated Under-Fire Air nozzles 28 respectively.

External ducts 20a, 26a, and 28a are all supplied by the same supply duct and the air within them is pressurised by the same fan.

[0056] Referring to Figure 6, when the combustion system is in use, air and fuel are injected into the combustion zone by combustion devices 20, to create a fireball 30 that spins around the longitudinal axis of the combustion chamber. The stoichiometric ratio within the fireball is typically 0.65 (excluding under-fire or over-fire air and external leakage into the combustion chamber).

[0057] Further air is injected into the combustion chamber underneath the fireball 30 by the Rotational Under-Fire Air nozzles 26, to create a secondary airstream 32. This airstream also swirls around the longitudinal axis of the combustion chamber, in the same rotational direction as the fireball 30. Thus, the air supplied by the Rotational Under-Fire Air nozzles helps to maintain and support the rotation of the fireball 30, even when low levels of air are provided directly to the fireball by the air nozzles of the combustion devices 20. Air supplied by the Rotational Under-Fire Air nozzles also helps to oxidise incompletely combusted fuel lying outside the fireball 30.

[0058] The flow path of air injected by the Rotational Under-Fire Air nozzles is also shown in Figure 7.

[0059] A further secondary airstream is injected along the axial direction of the combustion chamber by Separated Under-Fire Air nozzles 28. This airstream helps to oxidise the products of incomplete combustion which gather at the centre of the fireball 30.

[0060] The air supplied to the air nozzles of the combustion devices 20, the Rotational Under-Fire Air nozzles 26 and the Separated Under-Fire Air nozzles 28 originates from the same duct system and is pressurised by the same fan to a pressure of about 9mbar. It enters the combustion chamber at a velocity of 56 m/s.

[0061] The air supplied into the combustion chamber may include chemical agents for the reduction of e.g. SO_x and/or NO_x, as is known in the art.

[0062] Combustion products leave the combustion chamber along flue gas duct 14, and may subsequently pass through heat exchangers (not shown), as is known in the art.

[0063] The burner belt of the combustion chamber is provided with combustion devices that are known in the art. In the embodiments described above some of the air which is conventionally delivered to these nozzles is removed which reduces NO_x production. The air which was removed is redirected with more air to the Separated Under-Fire Air nozzles, Rotational Under-Fire Air nozzles and also to the Over-Fire Air system. Because air has been removed from the combustion devices in the main burner belt then the momentum of that air is not there to help the fireball rotate. Advantageously the redirected Rotational Under-Fire Air adds that momentum back so as to help keep the fireball circulating and to help centralise it in the middle of the furnace. The redirected Separated Under-Fire Air then attacks the unburnt fuel which accumulates in the centre of the fireball and the Over-

Fire Air either existing or added or modified by the present invention will help complete combustion of the fuel at the top of the furnace.

[0064] Referring to Figures 8 and 9, a combustion chamber 14' has a base 16' that is shaped as a hopper having two sides that are aligned (not shown) and two angled sides that are oriented towards each other. The two angled sides do not meet, but at their closest point define an aperture therebetween. The two angled sides further extend outwardly from the combustion chamber, such that they extend away from each other in a direction away from the combustion chamber.

[0065] Two under-fire air nozzles 28' are provided outside the combustion chamber 14' and arranged to direct gas into the combustion chamber 14' through the aperture provided between the angled sides of the base 16'. The two under-fire air nozzles are connected by a support brace 92. The two under-fire air nozzles are each mounted in a respective wall of an ash hopper 94 that is provided below the combustion chamber. Cross members 98,100 extend between the walls of the ash hopper 94 to support the support brace 92. In certain embodiments, the cross members 98,100 are omitted.

Claims

1. A combustion system (10) comprising a combustion chamber (12) and a flue gas duct (14) located downstream of the combustion chamber to receive combustion products from the combustion chamber, the combustion chamber having a base (16) and an enclosing wall (18) connecting the base to the flue gas duct, the combustion chamber being provided with a plurality of combustion devices (20), the combustion devices being configured to deliver fuel and gas into the combustion chamber so as to generate a fireball within a combustion zone (22) in the combustion chamber, the combustion devices further being configured such that the generated fireball rotates about an axis extending between the base and the flue duct, wherein the system comprises a secondary gas and/or air nozzle (28) at a location upstream of the combustion zone, the nozzle being for delivering gas and/or air into the combustion zone in a direction towards the flue duct, through the centre of the fireball and along its axis of rotation, and **characterized in that** a plurality of further secondary gas nozzles (26) is provided at a location upstream of the combustion zone, said plurality of secondary gas nozzles being configured to deliver gas into the combustion chamber so as to create a gas stream that rotates about the axis extending between the base and the duct.
2. A combustion system according to claim 1, wherein

the plurality of secondary gas nozzles are located 0.5-3 metres away from the combustion devices, measured along the axis extending between the base and the flue duct.

3. A combustion system according to claim 1 or claim 2, the system being arranged to supply gas to the combustion devices and the plurality of secondary gas nozzles from the
4. A combustion system according to claim 3, wherein the gas supplied to the combustion devices and the plurality of secondary gas nozzles is pressurised by the same fan.
5. A method of operating a combustion system according to any one of claims 1-4, comprising the step of delivering fuel and gas into the combustion chamber by means of the combustion devices to generate a fireball having a stoichiometry less than 0.9.
6. A method of operating a combustion system according to any one of claims 1-4, comprising the step of delivering gas into the combustion chamber via the plurality of secondary gas nozzles at a velocity of 40-70 m/s.

Patentansprüche

1. Verbrennungssystem (10), beinhaltend eine Verbrennungskammer (12) und einen Rauchgaskanal (14), der stromabwärts von der Verbrennungskammer liegt, um Brennprodukte von der Verbrennungskammer zu empfangen, wobei die Verbrennungskammer eine Basis (16) und eine einschließende Wand (18), die die Basis mit dem Rauchgaskanal verbindet, aufweist, wobei die Verbrennungskammer mit einer Vielzahl von Verbrennungsvorrichtungen (20) versehen ist, wobei die Verbrennungsvorrichtungen konfiguriert sind, Brennstoff und Gas in die Verbrennungskammer zu liefern, um innerhalb einer Verbrennungszone (22) in der Verbrennungskammer einen Feuerball zu generieren, wobei die Verbrennungsvorrichtungen ferner so konfiguriert sind, dass der generierte Feuerball um eine Achse rotiert, die sich zwischen der Basis und dem Rauchgaskanal erstreckt, wobei das System ferner eine sekundäre Gas- und/oder Luftdüse (28) an einer Stelle stromaufwärts von der Verbrennungszone beinhaltet, wobei die Düse dem Liefern von Gas und/oder Luft in die Verbrennungszone in einer Richtung zum Rauchgaskanal durch die Mitte des Feuerballs und entlang seiner Rotationsachse dient, und **dadurch gekennzeichnet, dass** eine Vielzahl von sekundären Gasdüsen (26) an einer Stelle stromaufwärts von der Verbrennungszone vorgesehen ist, wobei die Vielzahl von

sekundären Gasdüsen konfiguriert ist, Gas in die Verbrennungskammer zu liefern, um einen Gasstrom zu erzeugen, der die Achse rotiert, die sich zwischen der Basis und dem Kanal erstreckt.

2. Verbrennungssystem gemäß Anspruch 1, wobei die Vielzahl von sekundären Gasdüsen 0,5-3 Meter von den Verbrennungsvorrichtungen liegt, gemessen entlang der Achse, die sich zwischen der Basis und dem Rauchgaskanal erstreckt.
3. Verbrennungssystem gemäß Anspruch 1 oder Anspruch 2, wobei das System eingerichtet ist, um Gas von der gleichen Quelle an die Verbrennungsvorrichtungen und die Vielzahl von sekundären Gasdüsen zu liefern.
4. Verbrennungssystem gemäß Anspruch 3, wobei das Gas, das an die Verbrennungsvorrichtungen und die Vielzahl von sekundären Gasdüsen geliefert wird, vom gleichen Gebläse druckbeaufschlagt wird.
5. Verfahren zum Betreiben eines Verbrennungssystems gemäß einem der Ansprüche 1-4, beinhaltend den Schritt zum Liefern von Brennstoff und Gas in die Verbrennungskammer mittels der Verbrennungsvorrichtungen, um einen Feuerball zu generieren, der eine Stöchiometrie von weniger als 0,9 aufweist.
6. Verfahren zum Betreiben eines Verbrennungssystems gemäß einem der Ansprüche 1-4, beinhaltend den Schritt zum Liefern von Gas in die Verbrennungskammer mittels der Verbrennungsvorrichtungen über die Vielzahl von sekundären Gasdüsen mit einer Geschwindigkeit von 40-70 m/s.

Revendications

1. Système de combustion (10) comprenant une chambre de combustion (12) et une gaine de gaz d'évacuation (14) localisée en aval de la chambre de combustion afin de recevoir des produits de combustion provenant de la chambre de combustion, la chambre de combustion ayant une base (16) et une paroi d'enceinte (18) raccordant la base à la gaine de gaz d'évacuation, la chambre de combustion étant munie d'une pluralité de dispositifs de combustion (20), les dispositifs de combustion étant configurés de façon à délivrer du carburant et du gaz dans la chambre de combustion de sorte à générer une boule de feu au sein d'une zone de combustion (22) dans la chambre de combustion, les dispositifs de combustion étant configurés en outre de telle sorte que la boule de feu générée tourne autour d'un axe s'étendant entre la base et la gaine d'évacuation,

le système comprenant une buse secondaire de gaz et/ou d'air (28) au niveau d'une localisation en amont de la zone de combustion, la buse étant destinée à délivrer du gaz et/ou de l'air dans la zone de combustion dans un sens allant vers la gaine d'évacuation, à travers le centre de la boule de feu et le long de son axe de rotation, et **caractérisé en ce qu'**une pluralité de buses de gaz secondaires supplémentaires (26) est prévue au niveau d'une localisation en amont de la zone de combustion, ladite pluralité de buses de gaz secondaires étant configurée de façon à délivrer du gaz dans la chambre de combustion de sorte à créer un flux de gaz qui tourne autour de l'axe s'étendant entre la base et la gaine.

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2. Système de combustion selon la revendication 1, la pluralité de buses de gaz secondaires étant localisée en éloignement de 0,5-3 mètres par rapport aux dispositifs de combustion, mesurés le long de l'axe s'étendant entre la base et la gaine d'évacuation. 20
3. Système de combustion selon la revendication 1 ou la revendication 2, le système étant agencé de façon à fournir du gaz aux dispositifs de combustion et à la pluralité de buses de gaz secondaires à partir de la même source. 25
4. Système de combustion selon la revendication 3, le gaz fourni aux dispositifs de combustion et à la pluralité de buses de gaz secondaires étant pressurisé par le même ventilateur. 30
5. Procédé d'exploitation d'un système de combustion selon l'une quelconque des revendications 1-4, comprenant l'étape consistant à délivrer du carburant et du gaz dans la chambre de combustion au moyen des dispositifs de combustion afin de générer une boule de feu ayant une stoechiométrie de moins de 0,9. 35
6. Procédé d'exploitation d'un système de combustion selon l'une quelconque des revendications 1-4, comprenant l'étape consistant à délivrer du gaz dans la chambre de combustion via la pluralité de buses de gaz secondaires à une vitesse de 40-70 m/s. 45

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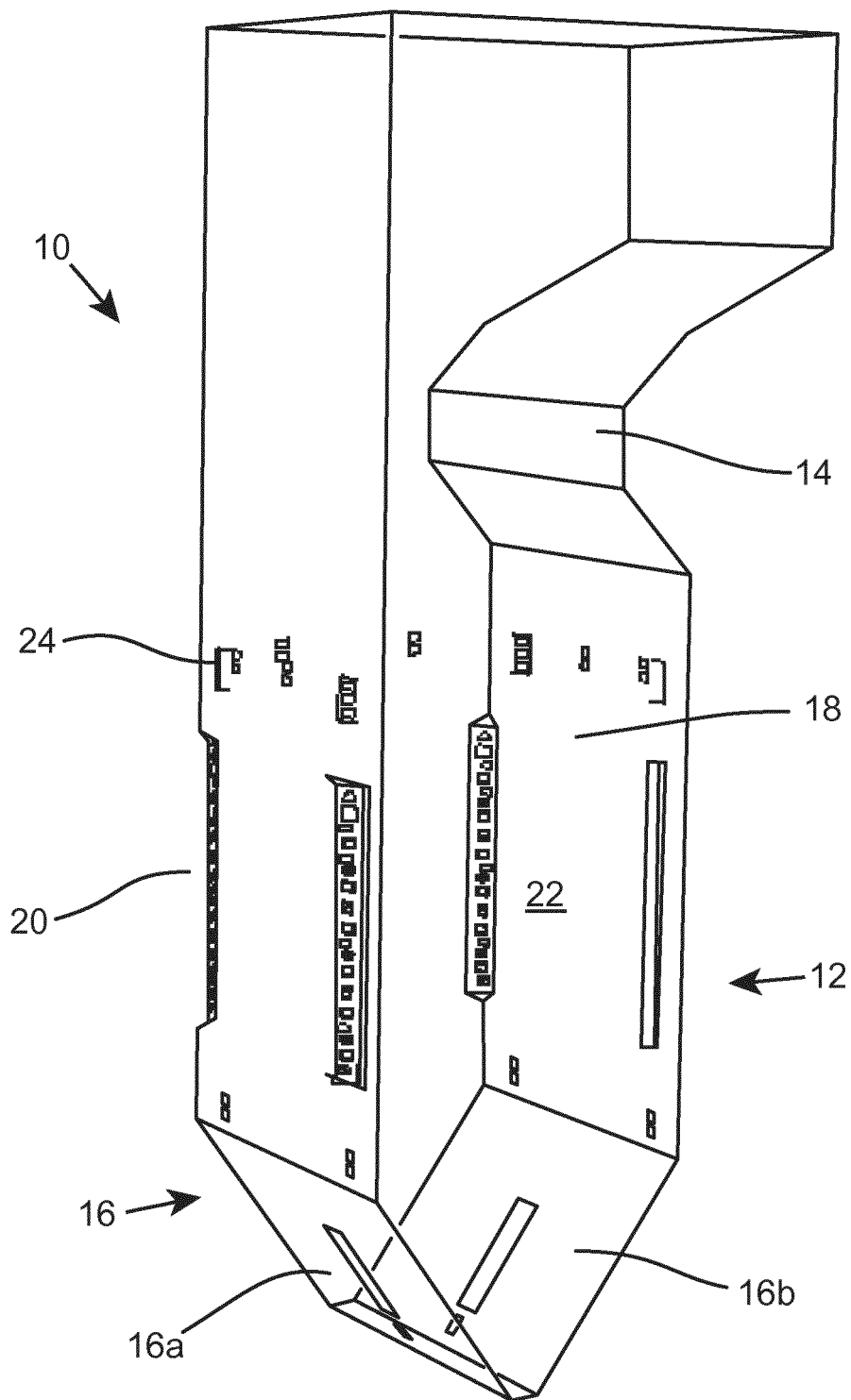


Fig. 1

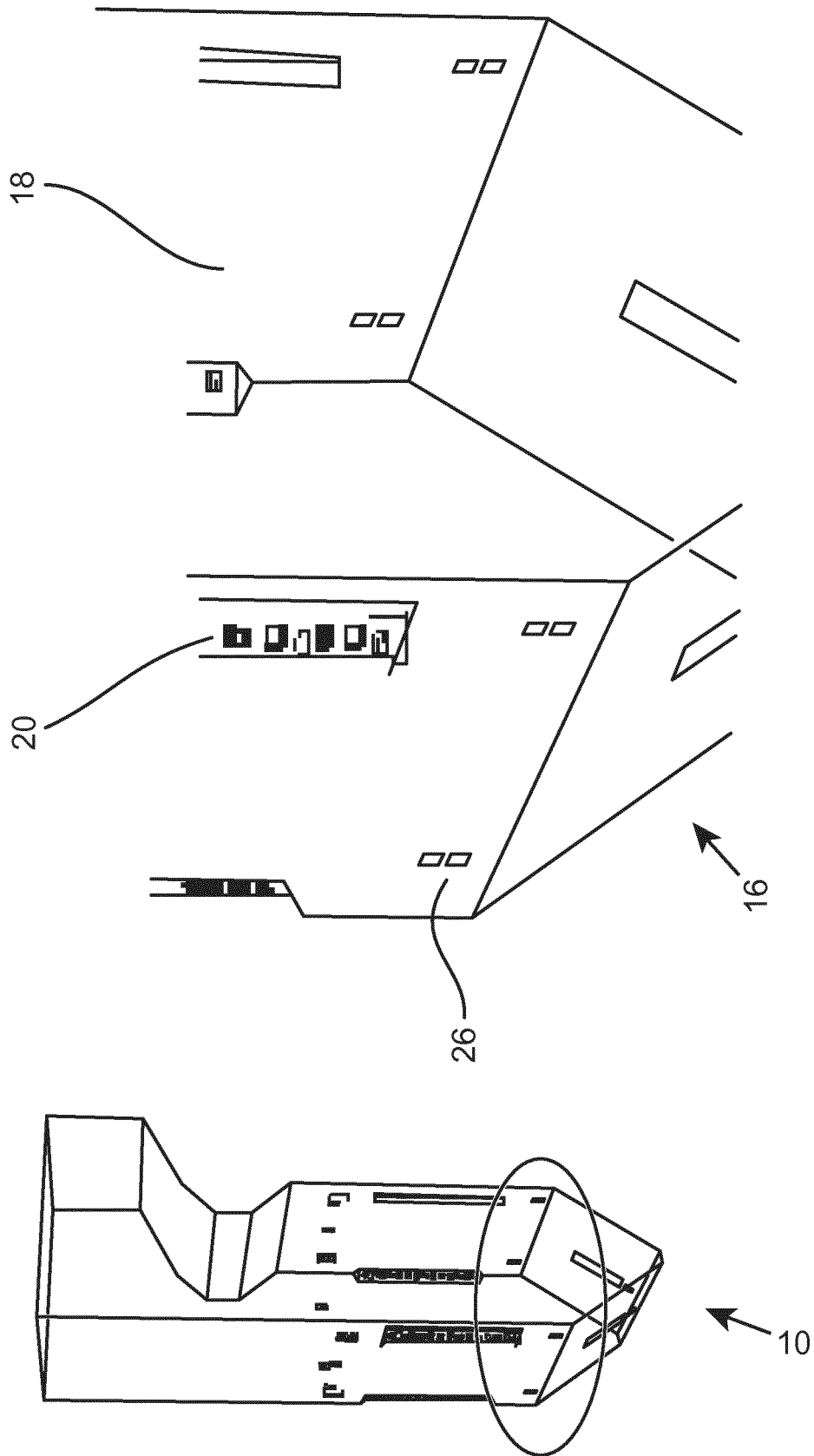


Fig. 2

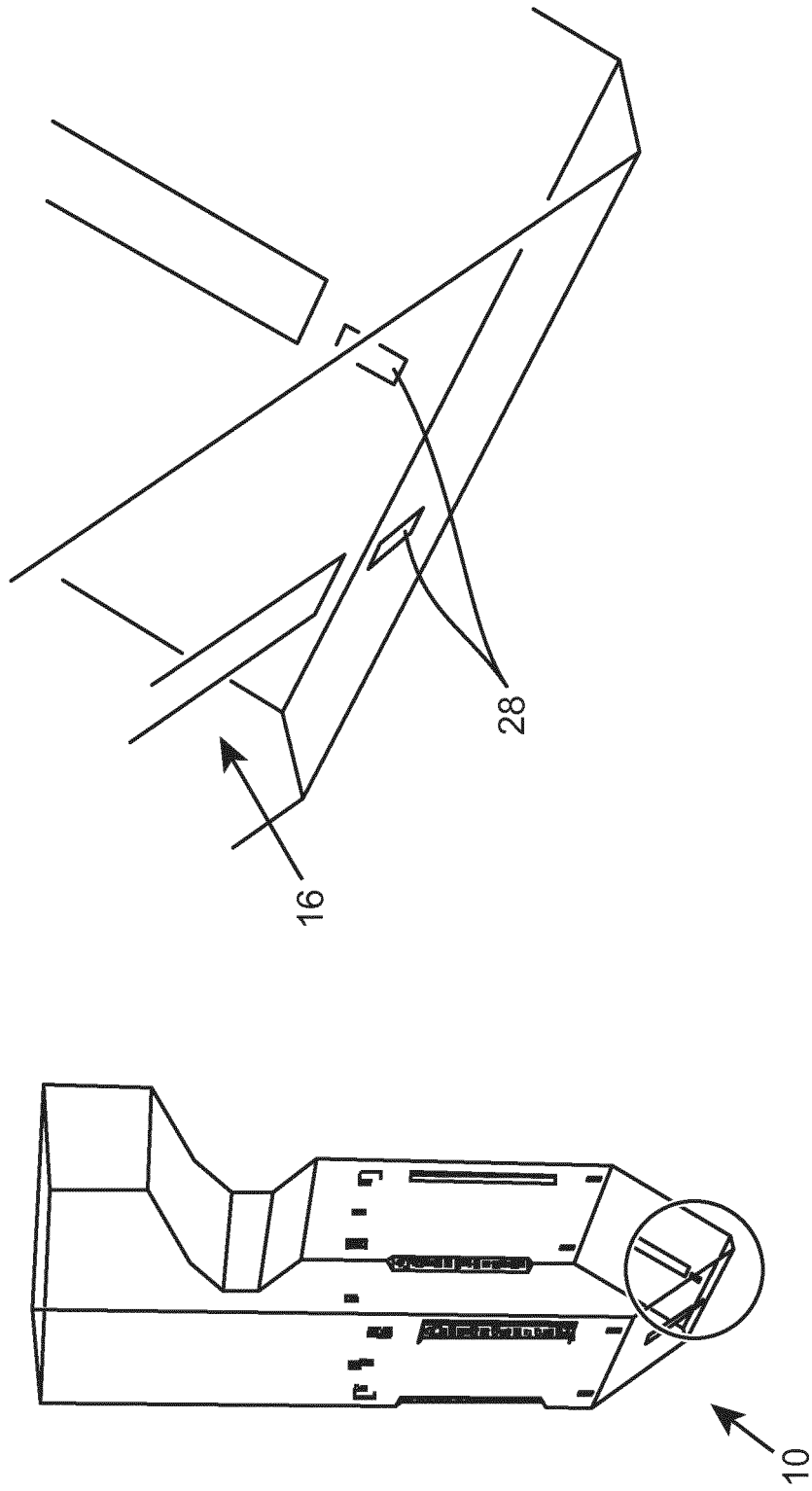
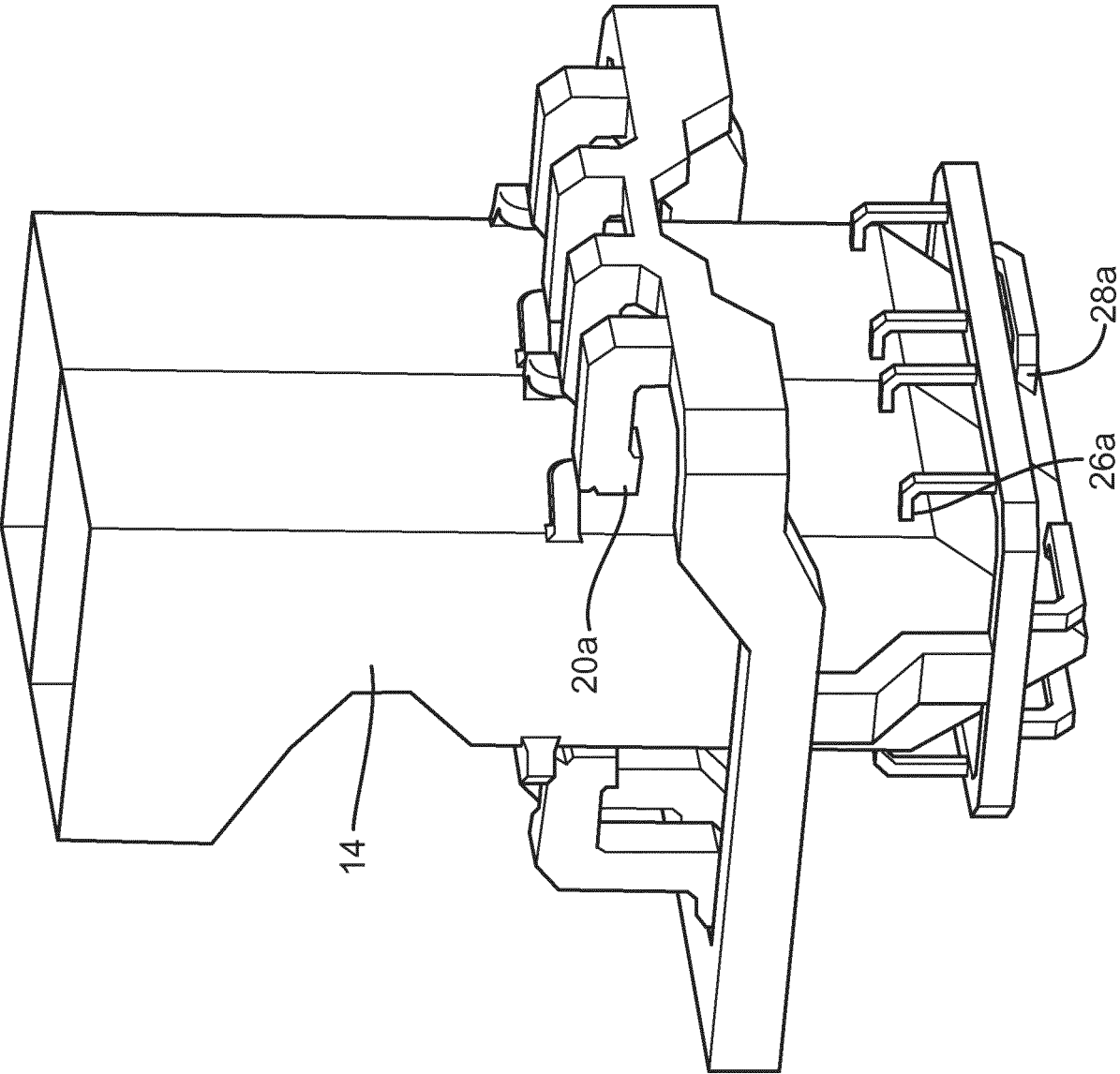


Fig. 3

Fig. 4



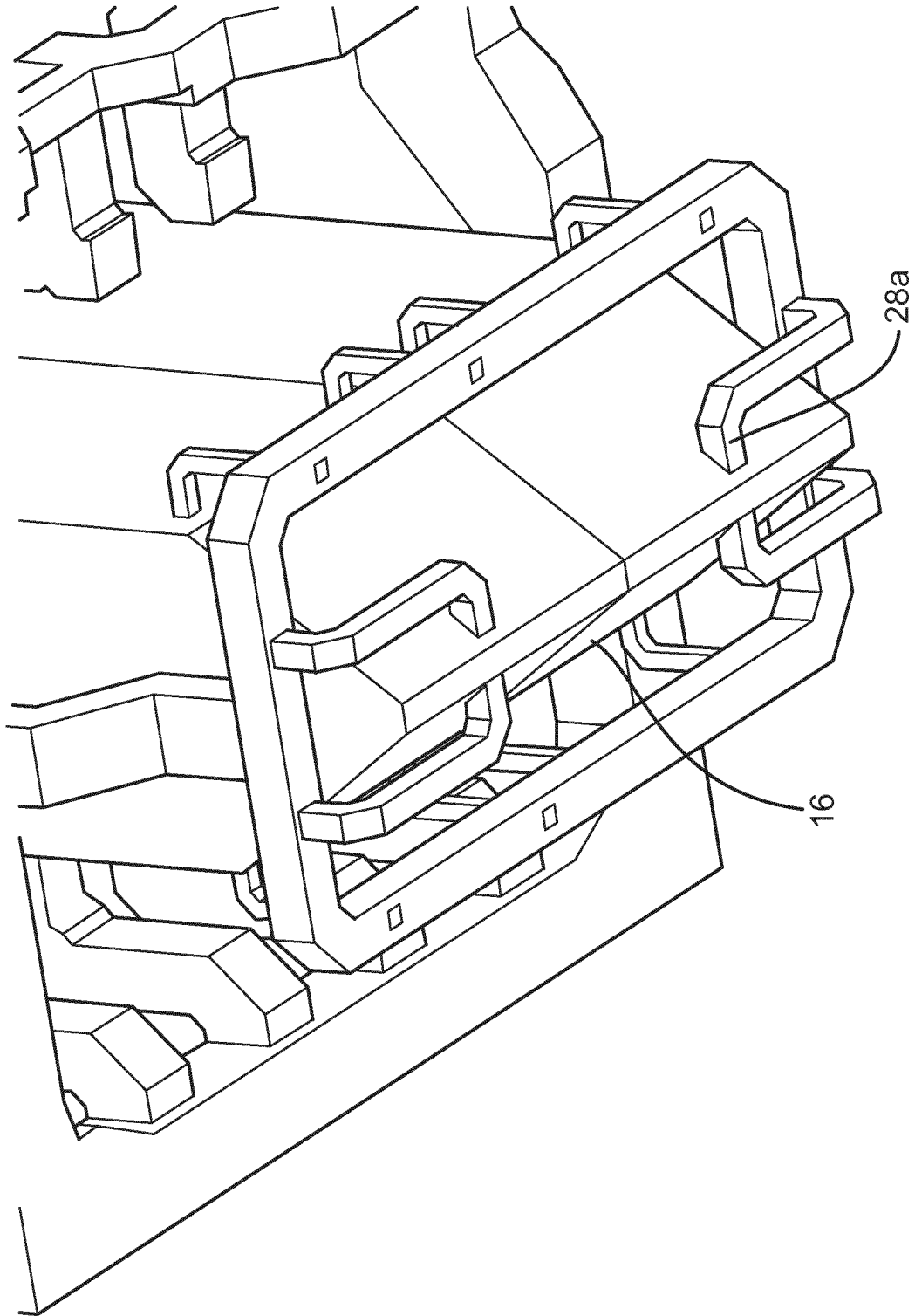


Fig. 5

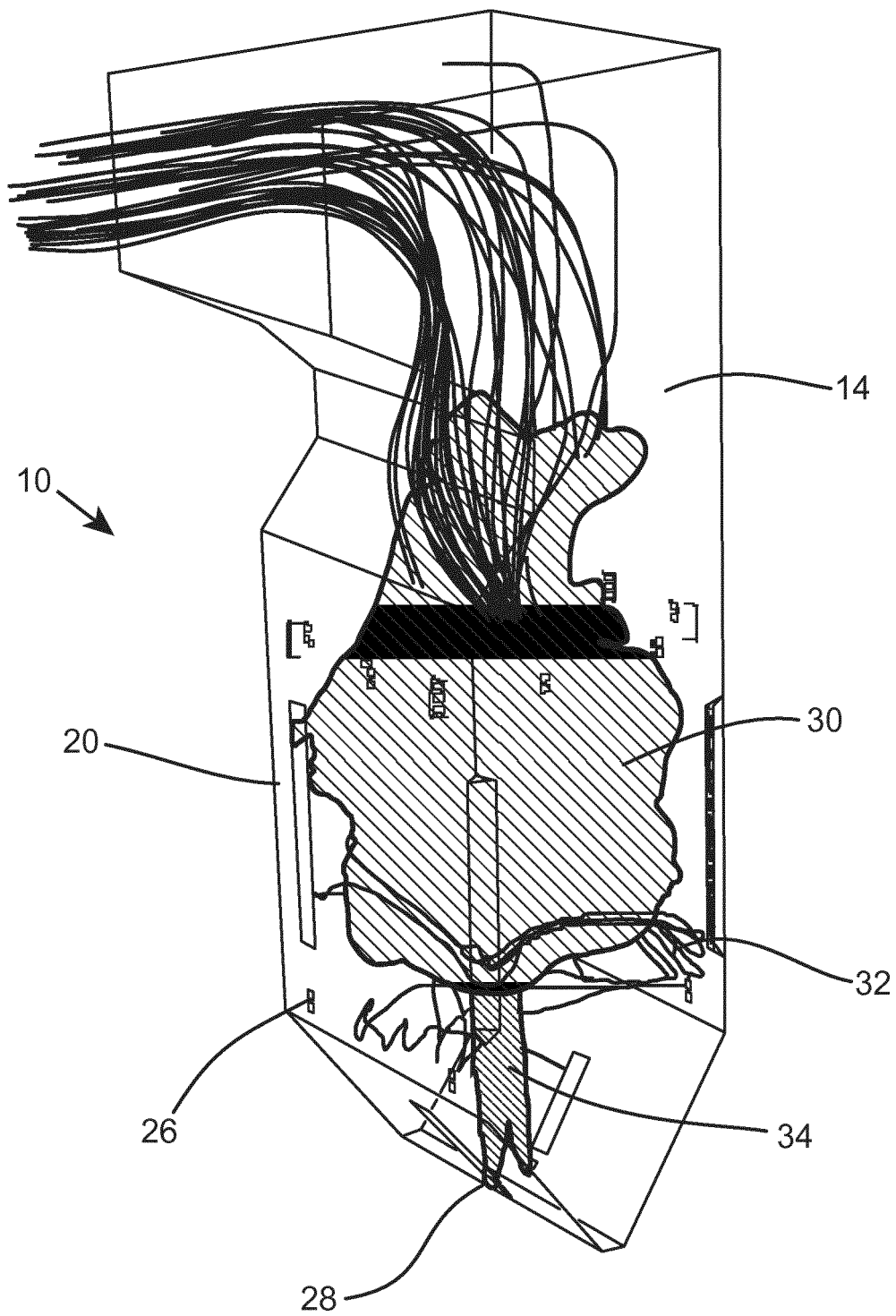


Fig. 6

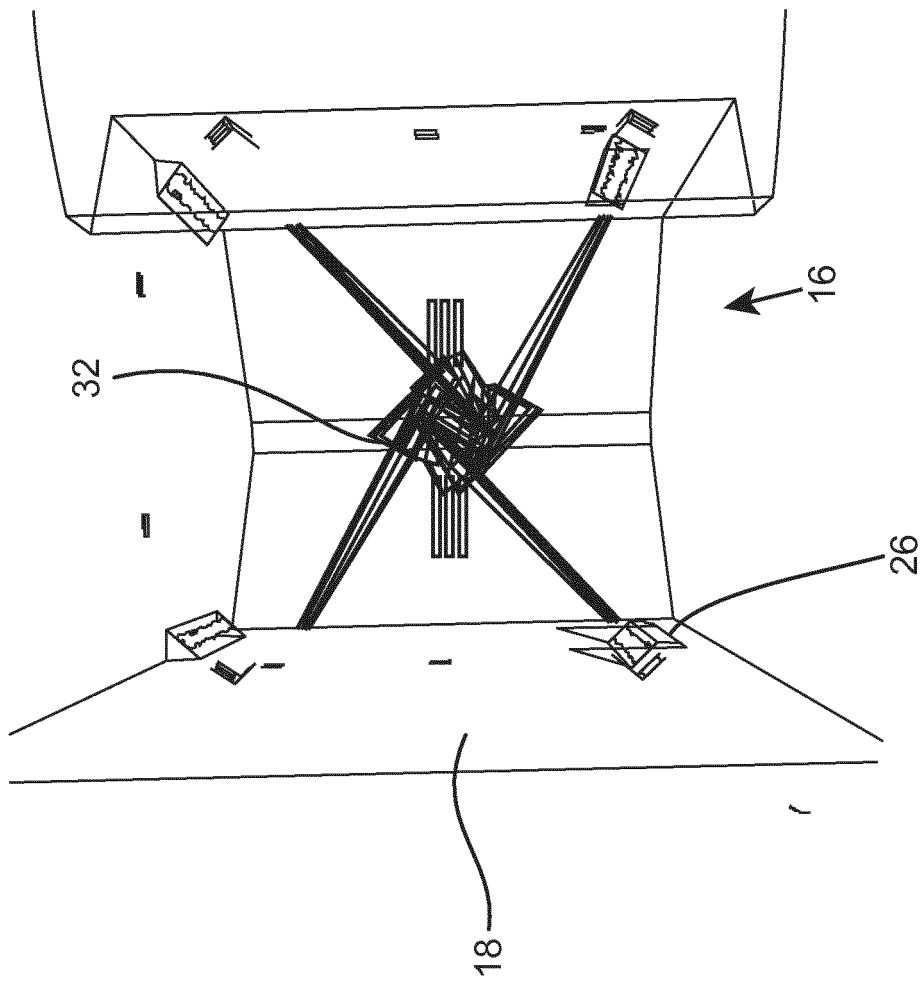


Fig. 7

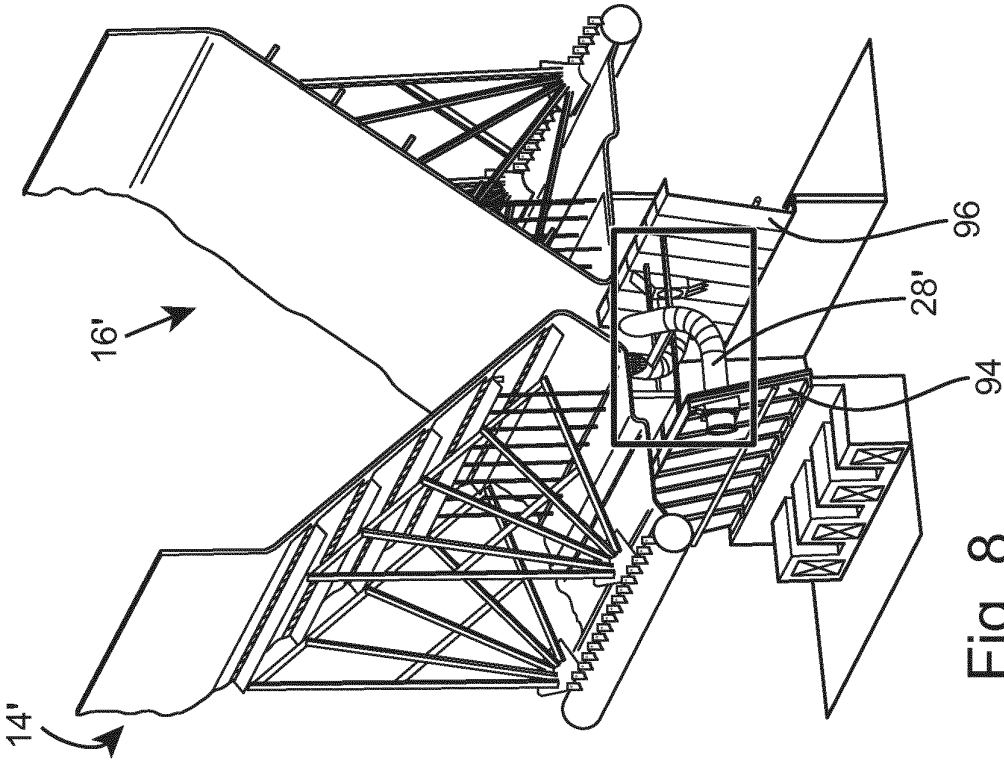


Fig. 8

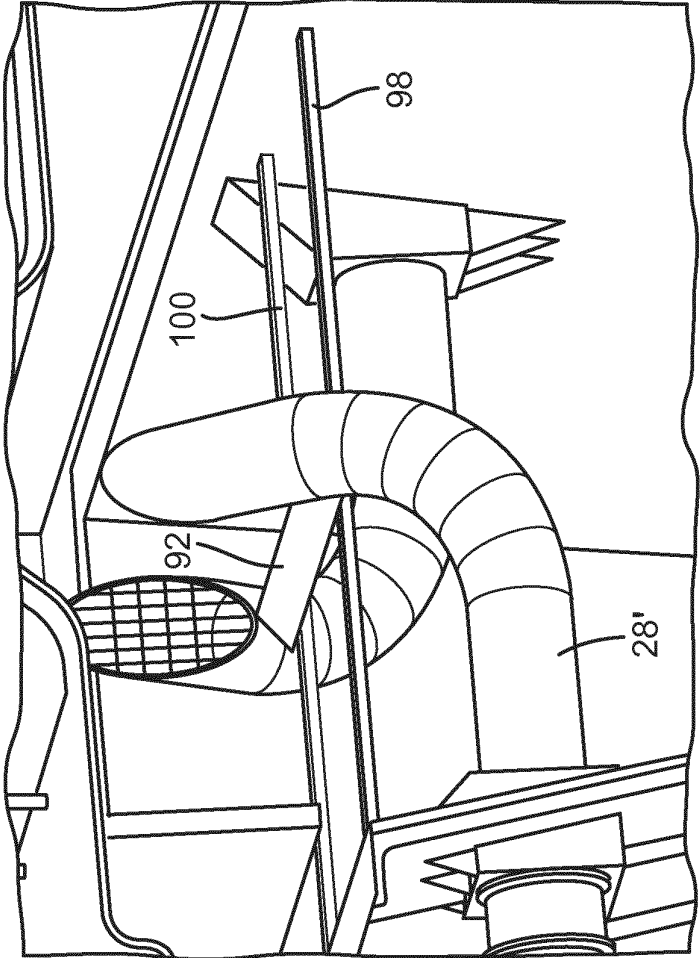


Fig. 9

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- EP 1435485 A [0005]