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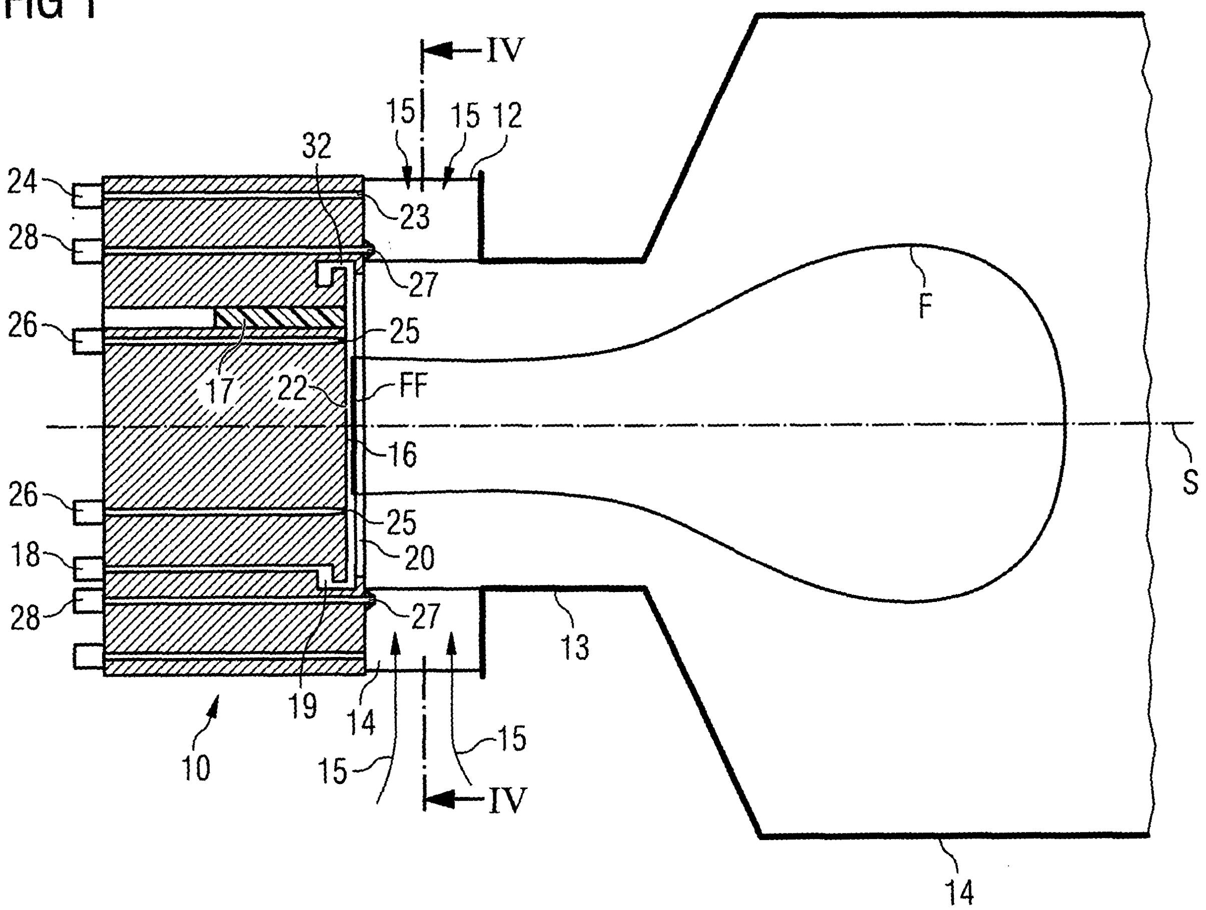
(54) **Burner in particular for a gas turbine combustor, and method of operating a burner**

(57) A burner is provided, comprising a burner face (16), a liquid fuel injection system and a liquid pilot fuel injection system. The liquid pilot fuel injection system comprises:
- a lip portion (20) which overlaps in parallel a circumferential section of the burner face (16) so as to form a space (54) between the lip portion (20) and the burner face (16),
- one or more air supply passages (32) leading into the space (54) between the lip portion (20) and the burner face (16); and
- one or more liquid pilot fuel supply passages (52) leading into the space (54) between the lip portion (20) and the burner face (16) and/or leading through the lip portion (20) into a space encircled by the lip portion (16).

FIG 1



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Description

[0001] The present invention relates to burner, in particular a gas turbine burner, as well as to a combustor, in particular a gas turbine combustor, and a method of operating the same.

[0002] In a gas turbine combustor a fuel is burned to produce hot pressurised exhaust gases which are then fed to a turbine stage where they, while expanding and cooling, transfer momentum to turbine blades thereby imposing a rotational movement on a turbine rotor. Mechanical power of the turbine rotor can then be used to drive a generator for producing electrical power or to drive a machine. However, burning the fuel leads to a number of undesired pollutants in the exhaust gas which can cause damage to the environment. Therefore, it takes considerable effort to keep the pollutants as low as possible. One kind of pollutant is nitrous oxide (NO_x). The rate of formation of nitrous oxide depends exponentially on the temperature of the combustion flame. It is therefore attempted to reduce the temperature over the combustion flame in order to keep the formation of nitrous oxide as low as possible. Another kind of pollutants, hydrocarbons, can result if a part of the fuel is not or not fully burnt in the combustor.

[0003] There are two main measures by which reduction of nitrous oxide pollutant is achievable. The first is to use a lean stoichiometry, e.g. a fuel/air mixture with a low fuel fraction. The relatively small fraction of fuel leads to a combustion flame with a low temperature and thus to a low rate of nitrous oxide formation. The second measure is to provide a thorough mixing of fuel and air before the combustion takes place. The better the mixing is the more uniformly distributed the fuel is in the combustion zone. This helps to prevent hotspots in the combustion zone which would arise from relative local maxima in the fuel/air mixing ratio, i.e. zones with high fuel /air mixing ratio compared to the average fuel/air mixing ratio in the combustor.

[0004] Modern gas turbine engines therefore use the concept of pre-mixing air and fuel in lean stoichiometry before the combustion of the fuel/air mixture. Usually the pre-mixing takes place by injecting fuel into an air stream in a swirling zone of a combustor which is located upstream from the combustion zone. The swirling leads to a mixing of fuel and air before the mixture enters the combustion zone. However, due to the lean stoichimetry mixing ratio the combustor becomes more prone to oscillations in the combustion system. Therefore, a pilot fuel injection system is usually used to stabilise the combustion. Such a pilot fuel injection system is, e.g. disclosed in US 6,532,726 B2. This document describes a combustor with uniform fuel/air premixing for low emissions combustion. It comprises an air inlet duct and a swirler disposed in the air inlet duct. The swirler is arranged such that in-taken air streams into a pre-combustion chamber in a direction more or less perpendicular to a main combustor axis. In other words, the swirler is arranged around the central part of the pre-chamber. A burner head face, which forms the upstream end of the pre-chamber, comprises four pilot fuel inlet openings which are arranged symmetrically at four positions off centre of the central axis of the burner. This configuration is beneficial for control of the nozzle temperature. However, in the case of a liquid fuel, the off centre nature of the insprayed fuel can result in a large proportion of spray missing the main combustion zone of the combustor. This in turn can lead to a fraction of unreacted fuel spray droplets which leave the combustor and the gas turbine engine in the form of unburnt hydrocarbons.

[0005] In addition, at part load conditions, the pilot fuel flow rate is high and therefore the propensity for forming fuel rich NO_x-producing pockets in the combustion zone is increased.

[0006] With respect to the mentioned prior art, it is an objective of the present invention to provide an improved burner, an improved combustor and a method of operating the same.

[0007] This objective is solved by a burner according to claim 1, a combustor according to claim 8 and a method of operating a combustor according to claim 9. The depending claims define advantageous developments of the invention.

[0008] An inventive burner, which may, in particular be a gas turbine combustor, comprises a burner face, a liquid fuel injection system and a liquid pilot fuel injection system. The liquid pilot fuel injection system comprises a lip portion which overlaps in parallel a circumferential section of the burner face so as to leave a space between the lip portion and the burner face. One or more air supply passages lead to the space between the lip portion and the burner face. Moreover, one or more liquid pilot fuel supply passages lead into the space between the lip portion and the burner face and/or through the lip portion into a space encircled by the lip portion.

[0009] This solution provides a modest change to the mechanical design of the fuel injection system described in US 6,532,726 B2 and ensures that liquid pilot fuel is injected into a region of relatively cool metal temperatures. By injecting air and liquid pilot fuel into the transition section through the space between the lip portion and the burner face a uniform injection of fuel into the region encompassing the front of the burner face and higher shear regions is achieved compared to the burner described in US 6,532,726 B2. The injected liquid fuel is atomised by the instreaming air before leaving the space between the lip and the burner face. By this atomising, zones of excessively high fuel concentration can be minimised which in turn will ensure reduced emissions of NO_x-emissions at part load conditions of the gas turbine engine. A similar effect can be achieved by injecting liquid pilot fuel through the lip portion into the space encircled by the lip portion.

[0010] The present invention provides a number of advantages over the combustor described in US 6,532,726 B2.

1. The pilot fuel is placed in a more uniform manner into the recirculating flow region of the combustion system.
2. The mechanism of injecting the liquid pilot fuel will be applicable for use for a wider range of fuels than the state of the art burner.
3. The injection mechanism is mechanically simple and can therefore be realised without a significant increase of the overall manufacturing costs.
4. The mechanism of injecting the liquid pilot fuel is located in the region of the combustor where the metal temperatures are lower than in the area of the off-centre liquid pilot fuel nozzles described in US 6,532,726 B2. It is therefore better for long term fuel coke mitigation.
5. By setting the separation between the lip portion and the burner face, the point of effective atomisation of the fuel droplets can be varied. This helps to ensure flexibility in the placement of fuel in the region of the vortex core shear layers.

[0011] In the inventive burner the one or more liquid fuel supply passages may lead into the space between the lip portion and the burner face and/or through the lip portion into the space encircled by the lip portion via one or more outlet openings which may be located in the burner face where it is overlapped by the lip portion and/or in the lip portion. If the outlet openings are arranged in the burner face where it is overlapped by the lip portion the fraction of liquid fuel coming into contact with the burner face prior to reaching the intended atomisation region between the lip and the burner face can be kept low. Moreover, an even flow of atomised droplets near the ignitor could ensure higher ignition reliability with this design.

[0012] The lip portion and/or the burner face may be made at least partly from a laminate structure into which at least those parts of the liquid pilot fuel supply passages are integrated which adjoin the outlet openings. This configuration provides the possibility of providing spray nozzles for extremely fine atomised spray using only hydraulic pressure. As by this technology drop sizes can be realised which are below usual impact atomisers, it can ensure that all liquid fuel is so injected as to not come into contact with the burner face prior to reaching the intended atomisation region. Moreover, in particular when the burner face is made from a laminate structure, a preheating of the liquid pilot fuel streaming through the laminate structure can be realised. By the preheating the liquid pilot fuel may at least partly evaporate.

[0013] The present invention can, in particular, be implemented with combustors which are designed so as to be operated with either liquid or gaseous fuel. In this case the inventive burner comprises a gaseous fuel injection system and a gaseous pilot fuel injection system which includes one or more gaseous pilot fuel supply passages. A downstream part of the one or more gaseous pilot fuel supply passages, i.e. a part which adjoins the outlet openings, is then identical to a downstream part of the one or more air supply passages of the liquid pilot fuel supply passage. In other words, when the combustor is operated with the liquid fuel, the passages for supplying gaseous pilot fuel may be used to provide the atomising air for the liquid pilot fuel injection. This reduces the number of additional passages which are necessary to realise the liquid pilot fuel injection mechanism. Such a burner advantageously comprises an associated switch mechanism for switching between gaseous fuel supply and air supply through the identical downstream parts. Feeding of the air to the gaseous pilot fuel supply passages may, e.g. be realised by one or more bleed pipes which connect the passages to an air supply, in particular, to a compressor section of the gas turbine engine.

[0014] In addition to the liquid pilot fuel supply system described above, with the respect to the present invention, conventional liquid pilot fuel supply passages, i.e. supply passages leading to openings in a section of the burner face which is not overlapped by the lip, as described, for example, in US 6,532,726 B2, may be additionally present. By setting the distribution of liquid pilot fuel between the conventional passages and the passages described in the invention, the pilot fuel injection can be optimised.

[0015] An inventive combustor, which may, in particular, be a gas turbine combustor, comprises an inventive burner, a combustion chamber (which may also be called a main chamber) and a transition section (which may also be called a pre-chamber) which is arranged in flow series between the burner and the combustion chamber. The burner face forms the upstream end face of the transition section. In general, the transition section may be implemented as a one part continuation of the burner towards the combustion chamber, as a one part continuation of the combustion chamber towards the burner, or as a separate part between the burner and the combustion chamber.

[0016] According to the invention a method of operating a combustor, in particular a gas turbine engine combustor, which comprises a burner, a combustion chamber (which may also be called main chamber) and a transition section (which may also be called pre-chamber) where the transition section is arranged in flow series between the burner and the combustion chamber is also provided. The burner comprises a burner face which forms the upstream end face of the transition section, a liquid fuel injection system, a liquid pilot fuel injection system, a gaseous fuel injection system and a gaseous pilot fuel injection system which comprises a lip portion overlapping in parallel a circumferential section of the burner face so as to leave a space between the lip portion and the burner face and one or more gaseous pilot fuel supply passages leading into the space between the lip portion and the burner face. In the inventive method air is led into the space between the lip portion and the burner face through at least a downstream part of the one or more gaseous pilot fuel supply passages so as to form an air stream streaming through said space when the combustor is operated in a liquid fuel mode. Moreover, liquid pilot fuel is injected into the air stream streaming through the space between the lip portion and the burner face and/or liquid pilot fuel is injected through the lip portion into an air stream streaming through the space encircled by the lip portion. By injecting the liquid pilot fuel into the air stream an atomisation of the liquid pilot fuel can be achieved, and thus the advantages already mentioned with respect to the inventive combustor.

[0017] In an advantageous development of the inventive method, the liquid pilot fuel is at least partially preheated before it is injected into the air stream streaming through the space between the lip portion and the burner face and/or before it is injected through the lip portion into the air stream streaming through the space encircled by the lip portion.

[0018] Additional pilot fuel may also be injected directly into the transition section and/or the combustion chamber through outlet openings in a section of the burner face where it is not overlapped by the lip portion. As already mentioned by setting the ratio of liquid pilot fuel which is injected into the air stream streaming through the space between the lip portion and the burner face and the liquid pilot fuel which is injected directly into the transition section and/or the combustion chamber the effect of the pilot fuel injection may be optimised.

[0019] Further features, properties and advantages of the present invention will become clear from the following description of particular embodiments with reference to the accompanying drawings.

[0020] Figure 1 schematically shows a gas turbine engine combustor according to the invention.

[0021] Figure 2 shows a part of the burner of the combustor shown in Figure 1 in a partly sectional perspective view.

[0022] Figures 3a and 3b show details from Figure 2.

[0023] Figure 4 shows an alternative embodiment to Figures 3a and 3b.

[0024] Figure 5 shows another alternative embodiment.

[0025] Figure 6 shows a modification of the embodiment shown in Fig. 5.

[0026] Referring now to Figure 1, a longitudinal section of a combustor according to the invention is illustrated. The combustor comprises a burner 10, including a burner head portion 11 attached to a radial inflow swirler portion 12, a transition section 13, and a main combustion chamber 14. The main chamber 14 has a diameter larger than that of the pre-chamber 13. In particular, the transition piece 13 may also be referred to as a pre-chamber in regard to the combustion chamber. The combustor shows, in general, a rotational symmetry with respect to a rotational axis S.

[0027] In an operation compressed air, flowing in the direction of the arrows 15 shown in Figure 1, is supplied to the combustor (usually from a gas turbine compressor) and enters the pre-chamber 13 in a direction substantially perpendicular to the symmetry axis S. A tangential component relative to a circle centred around a symmetry axis is imposed to the inflowing compressed air 15 by the swirler 12.

[0028] The air taken in through the swirler 12 mixes with fuel injected into the swirler by fuel injectors 23, 27 and, on arriving in the pre-chamber 13, the mixture is ignited by means such as an electric ignitor unit 17. Once lit, the flame continues to burn without further assistance from such ignitor. The combustor shown in Figure 1 may either be operated with gaseous or liquid fuel.

[0029] When operated with gaseous fuel, the fuel is injected through the gaseous fuel injections system. In addition, pilot gas is injected through a gaseous pilot fuel injection system comprising an annular pilot gas gallery 19 which is in flow connection via either a series of spaced-apart openings 32 or a continuous annular duct, to inject pilot gas to the underside of a directing means in the form of circumferential lip 20 extending radially inwards towards the symmetry axis S of the combustor. The pilot gas is fed from connectors 18 through interconnecting ducts, as shown in Figure 1. The lip deflects the pilot gas across a central portion 22 of the burner face 16, i.e. radially inwards in a direction generally normal to the symmetry axis S. The pilot gas mixes with incoming compressed air 15 and main gas-fuel exiting the swirler 12. The main gas fuel is introduced into the swirler by openings 23 which are located in the burner face 16 at the swirler air inlet region, i.e. in a radially outer part of the burner face 16 and are fed by connectors 24 through interconnecting ducts, as shown.

[0030] Also shown in Figure 1 are the combustion flame envelope represented by the boundary line F and the flame front face FF. The flame front face FF is created by recirculation of fluid entering the combustion chamber along the radially outer parts of the chamber back along the central part of the chamber (along symmetry axis S) towards the burner face 16 and then back again towards the main chamber 14. The front face FF itself is the point at which the axial flow in the direction of the burner 10 turns back towards the main chamber 14.

[0031] The burner 10 may also be operated with liquid fuel. Therefore, it comprises a liquid fuel injection system and a liquid pilot fuel injection system. The main liquid fuel injection system is formed from injection openings 27 in the burner face 16 which are located radially inwards with respect to the gas fuel inlet holes 23 at the swirler air inlet region. The liquid fuel injection openings 27 are fed from connectors 28 through interconnecting ducts.

[0032] The liquid pilot fuel injection system (see Figure 2) comprises four liquid pilot fuel openings 25 which are fed from connectors 26 through interconnecting ducts, as shown in Figure 1. The liquid pilot fuel injections openings 25 are located in the central part 22 of the burner face 16. They are located symmetrically around the symmetry axis S. In addition, the liquid pilot fuel injection system comprises second liquid pilot fuel injection openings 50 which are located in a section of the central part 22 of the burner face 16 which is overlapped by the lip 20 of the gaseous pilot fuel injection system (see Figures 3a and 3b). These injection openings 50 are fed through ducts 52 extending through the burner head 11.

[0033] In operation, liquid pilot fuel is, on the one hand, introduced into the pre-chamber through the first liquid pilot fuel injection openings 25 and, on the other hand, through the second liquid pilot fuel injection openings 50. In addition, in the liquid fuel operation mode, air instead of gaseous fuel is injected into the pre-chamber 13 through the gallery 19 and the openings 32. The air is fed to the gallery 19 by bleed passages interconnecting the gallery 19 to a compressor section of the gas turbine engine. Pilot fuel injected through the openings 50 is introduced into the air stream streaming through the space 54 between the lip 20 and the overlapped part of the burner face 16. Thereby, an atomisation of the liquid pilot fuel introduced through the openings 50 takes place before it leaves the space 54. By this configuration a part of the liquid pilot fuel is injected in an area of the burner face 16 which is relatively cool. Moreover, it provides a uniform injection of fuel into the air streams 15 through the swirler portion 12 ensuring that localised regions of excessively high fuel concentration are minimised.

[0034] A second embodiment of the liquid pilot fuel injection system is shown in Figure 4. While, in the first embodiment, the second pilot fuel injection openings 50 are fed through ducts 52 extending through the gallery 19 and the burner head 11, in the second embodiment, shown in Figure 4, a macro-laminate structure is used for feeding second liquid pilot fuel injection openings 150. The laminate structure forms micro ducts 152 extending from a central duct 154 located in the burner heads 11 centre to the openings 150. This configuration improves the atomisation of the injected liquid fuel in the air stream in the space 54. In the central duct 154 and more so in the micro ducts 152 a preheating of the pilot fuel takes place which may also lead to an at least partial evaporation of the pilot fuel.

[0035] In a third embodiment, as shown in Figure 5, the second liquid pilot fuel injections openings 250 are located in the face of the lip 20 which is directed to the burner face 16 rather than in the burner face 16 itself. The use of a macro-laminate structure of the lip in the configuration shown in Figure 5 in which micro ducts 252 lead to the injection openings 250 in the lips face ensure that all fuel so injected does not come into contact with the burner face 16 prior to reaching the intended atomisation region of the space 54 between the lip 20 and the burner face 16.

[0036] In a modification of third embodiment the micro ducts 256 may lead to injection openings 254 located in the front face 21 of the lip 20, i.e. the face which is directed towards the centre of the burner 10, instead to injection openings 250 located in the face of the lip 20 which is directed to the burner face 16. Such a modification is shown in Fig. 6. By this modification the fuel is injected where the air stream 15 coming from the swirler portion 12 meets with the air stream coming from the gallery 19.

[0037] In a further modification, the micro ducts 250 leading to injection openings 250 located in the face of the lip 20 which is directed to the burner face 16 and/or the micro ducts 256 leading to the injection openings 254 located in the front face 21 of the lip 20 may extend from a central duct 154, as in the second embodiment. Note that a combination of the openings and micro ducts of the second embodiment with the openings and micro ducts of the third embodiment and its modifications is possible.

[0038] With the described gas turbine engine combustor, the performance of liquid pilot fuel injection can be improved with minimal impact on the gaseous fuel operation of the burner. As the annular gallery 19, which is used in the gaseous fuel mode for feeding the pilot gas is, in the liquid fuel mode, used for feeding the atomisation air for atomising the liquid pilot fuel, the design changes which are necessary with respect to a conventional burner as described in US 6,532,726 B2 to implement the inventive combustor concept are minimal.

Claims

1. A burner, in particular a gas-turbine engine burner, comprising a burner face (16), a liquid fuel injection system and a liquid pilot fuel injection system wherein the liquid pilot fuel injection system comprises:

    - a lip portion (20) which overlaps in parallel a circumferential section of the burner face (16) so as to form a space (54) between the lip portion (20) and the burner face (16),
    - one or more air supply passages (32) leading into the space (54) between the lip portion (20) and the burner face (16); and
    - one or more liquid pilot fuel supply passages (52, 152, 252, 256) leading into the space (54) between the lip portion (20) and the burner face (16) and/or leading through the lip portion (20) into a space encircled by the lip portion (16).

2. The burner as claimed in claim 1, wherein the one or more pilot fuel supply passages (52, 152, 252, 256) lead into the space (54) between the lip portion (20) and the burner face (16) and/or through the lip portion (20) into the space encircled by the lip portion (16) via one or more outlet openings (50, 150, 250, 254) which are located in the section of the burner face (16) overlapped by the lip portion (20) and/or in the lip portion (20).

3. The burner as claimed in claim 1 or claim 2, wherein the lip portion (20) and/or the burner face (16) is/are at least partly made from a laminate structure, into which at least those parts of the liquid pilot fuel supply passages (152, 252) are integrated which adjoin the

outlet openings (150, 250).

4. The burner as claimed in any one of the preceding claims, wherein the burner (10) further comprises a gaseous fuel injection system and a gaseous pilot fuel injection system including one or more gaseous pilot fuel supply passages (19, 32), and wherein an downstream part (19, 32) of the one or more gaseous pilot fuel supply passages are identical to the downstream part (19, 32) of the one or more air supply passages of the liquid pilot fuel supply system.

5. The burner as claimed in claim 4, wherein the identical downstream part comprises a gas gallery (19) which is connected or connectable to an air supply via one or more bleed pipes.

6. The burner as claimed in claim 4 or claim 5, further comprising a switch mechanism for switching between gaseous fuel supply and air supply through the identical downstream part (19, 32).

7. The burner as claimed in any one of the preceding claims, wherein additional liquid pilot fuel supply passages are present leading to openings (25) in a section of the burner face (16) which is not overlapped by the lip (20).

8. A combustor, in particular a gas-turbine engine combustor, comprising:

- a burner as claimed in any of the preceding claims;
- a combustion chamber (14) and
- a transition section (13) being arranged in flow series between the burner (10) and the combustion chamber (14), the burner face (16) forming the upstream end face of the transition section (13).

9. A method of operating a combustor, in particular a gas-turbine engine combustor, comprising a burner (10) including a burner face (16), a liquid fuel injection system, a liquid pilot fuel injection system; a gaseous fuel injection system and a gaseous pilot fuel injection system;

- a combustion chamber (14) and
- a transition section (13) being arranged in flow series between the burner (10) and the combustion chamber (14), the burner face (16) forming the upstream end face of the transition section (13);
- wherein the gaseous pilot fuel injection system comprises:
- a lip portion (20) which overlaps in parallel a circumferential section of the burner face (16) so as to form a space (54) between the lip portion (20) and the burner face (16),
- one or more gaseous pilot fuel supply passages (19, 32) leading into the space (54) between the lip portion (20) and the burner face (16);
- the combustor being operable in a gaseous fuel mode and in a liquid fuel mode,

wherein, in the liquid fuel mode, air is led into the space (54) between the lip portion (20) and the burner face (16) through at least an downstream part of the one or more gaseous pilot fuel supply passages (19, 32) so as to form an air stream streaming through that space (54) and wherein liquid pilot fuel is injected into the air stream streaming through the space (54) between the lip portion (20) and the burner face (16) and/or liquid pilot fuel is injected through the lip portion (20) into an air stream streaming through the space encircled by the lip portion (20).

10. The method as claimed in claim 9, wherein the pilot fuel is at least partially preheated before it is injected into the air stream streaming through the space (54) between the lip portion (20) and the burner face (16) and/or injected through the lip portion (20) into the air stream streaming through the space encircled by the lip portion (20).

11. The method as claimed in claim 9 or 10, wherein additional pilot fuel is injected directly into the transition section (13) and/or the combustion chamber (14) through outlet openings (25) in a section of the burner face (16) which is not overlapped by the lip portion (20).

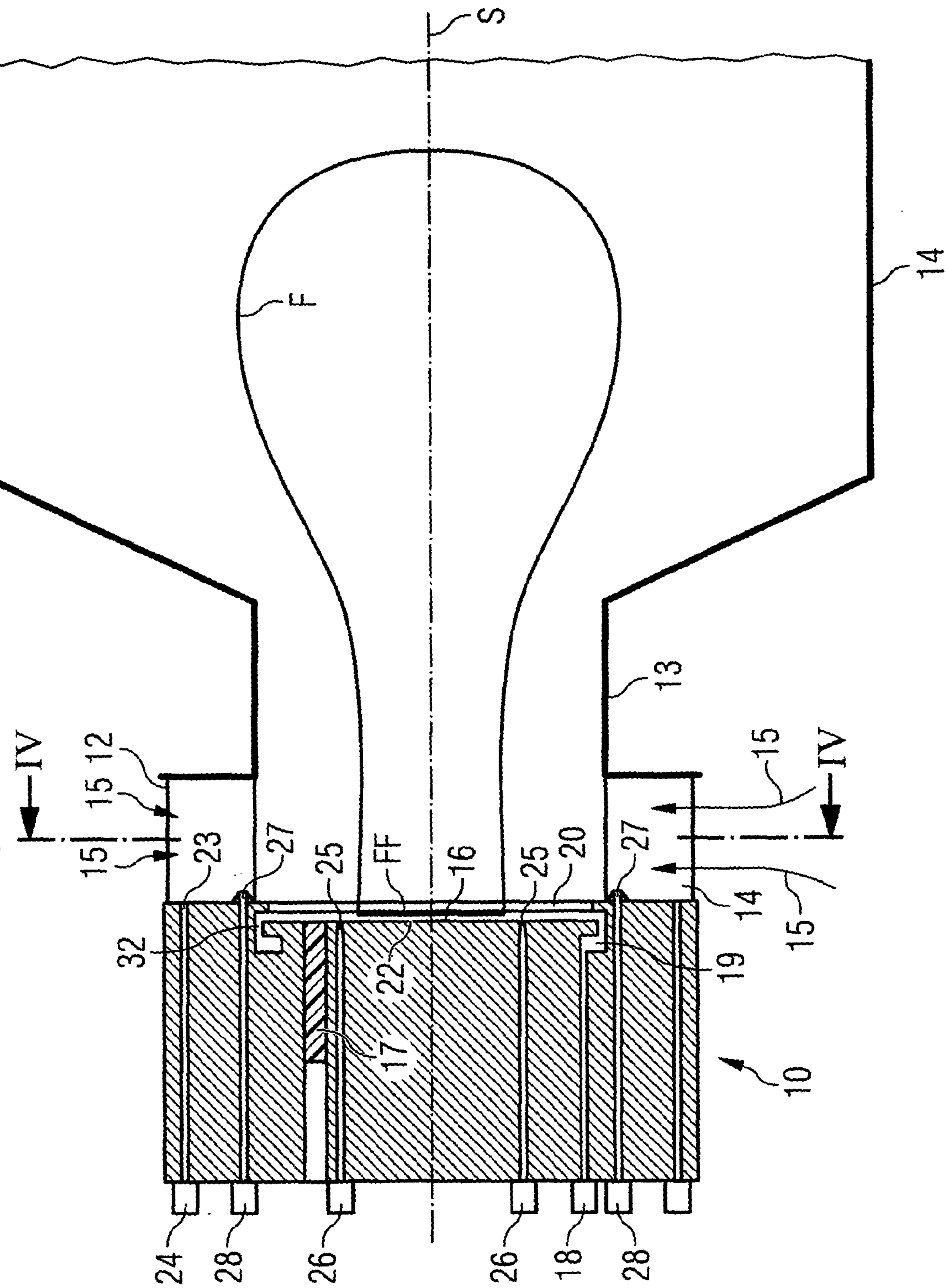


FIG 1

FIG 2

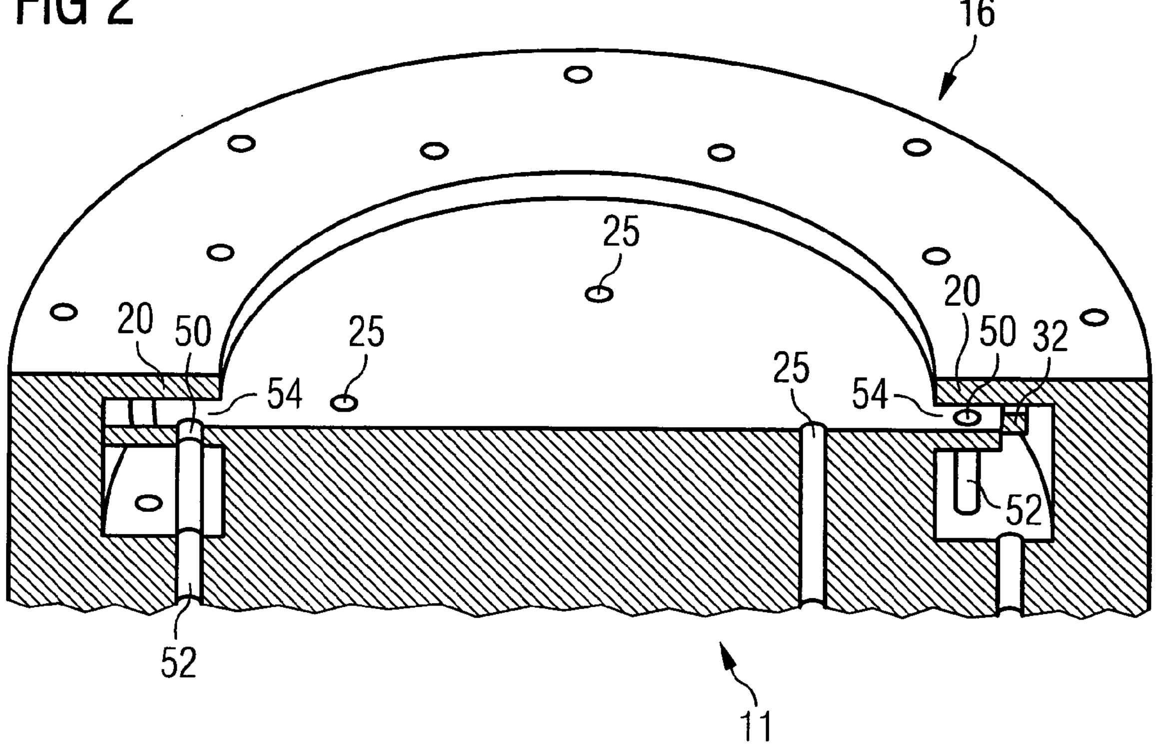


FIG 3A

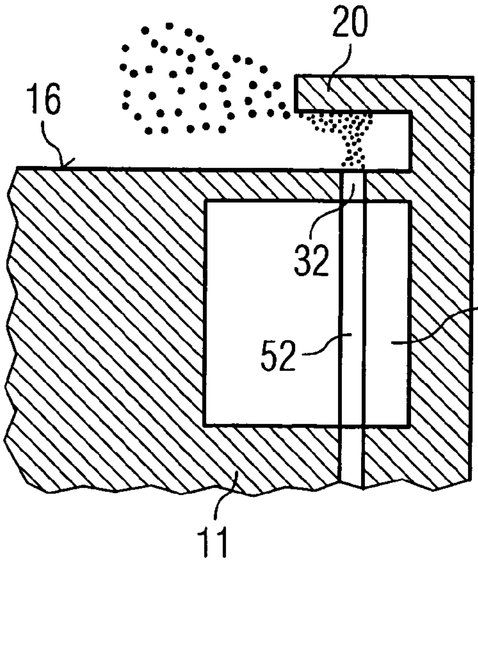


FIG 3B

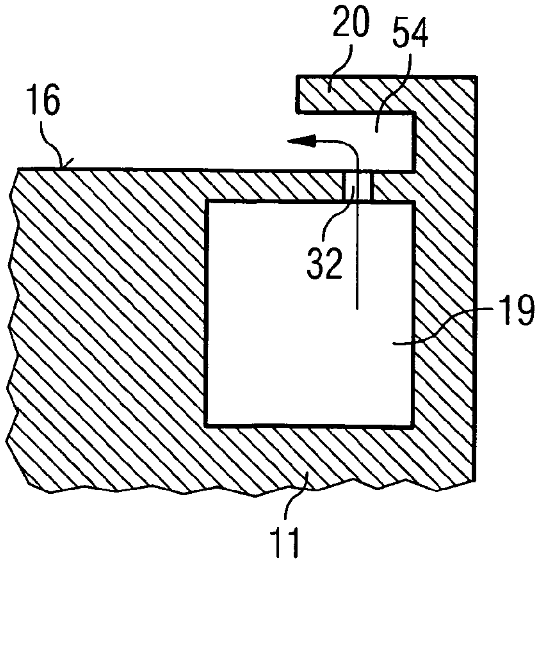


FIG 4

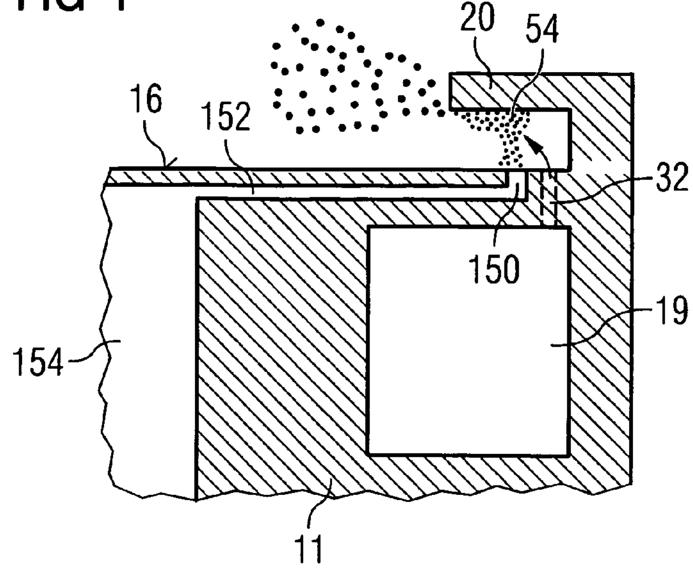


FIG 5

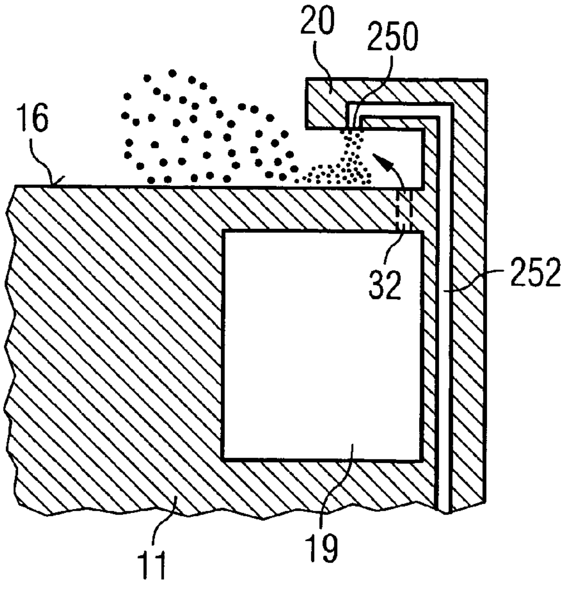
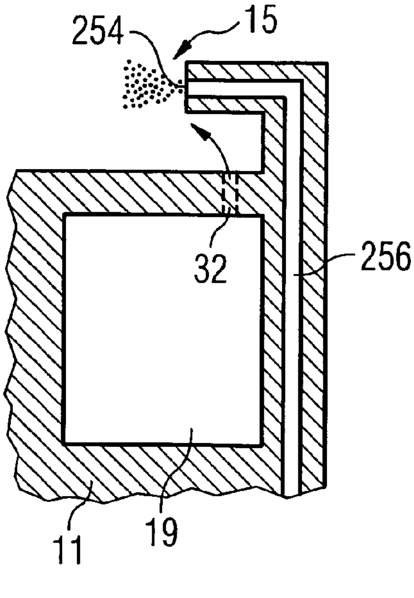


FIG 6



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EUROPEAN SEARCH REPORT

Application Number
EP 06 00 5107

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	GB 2 104 641 A (ANATOLY ALEXEEVICH * CHERNY) 9 March 1983 (1983-03-09) * page 2, line 9 - line 18; figures 1,8 * -----	1,9	
A	DE 103 31 575 A1 (WEBASTO THERMOSYSTEME GMBH; WEBASTO AG) 10 February 2005 (2005-02-10) * paragraphs [0030], [0031] * -----	1,8,9	
A	US 5 450 724 A (KESSELI ET AL) 19 September 1995 (1995-09-19) * column 3, line 58 - column 4, line 20 * -----	1,8,9	TECHNICAL FIELDS SEARCHED (IPC) F23R F23C F23D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	16 August 2006	Mougey, M

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 06 00 5107

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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