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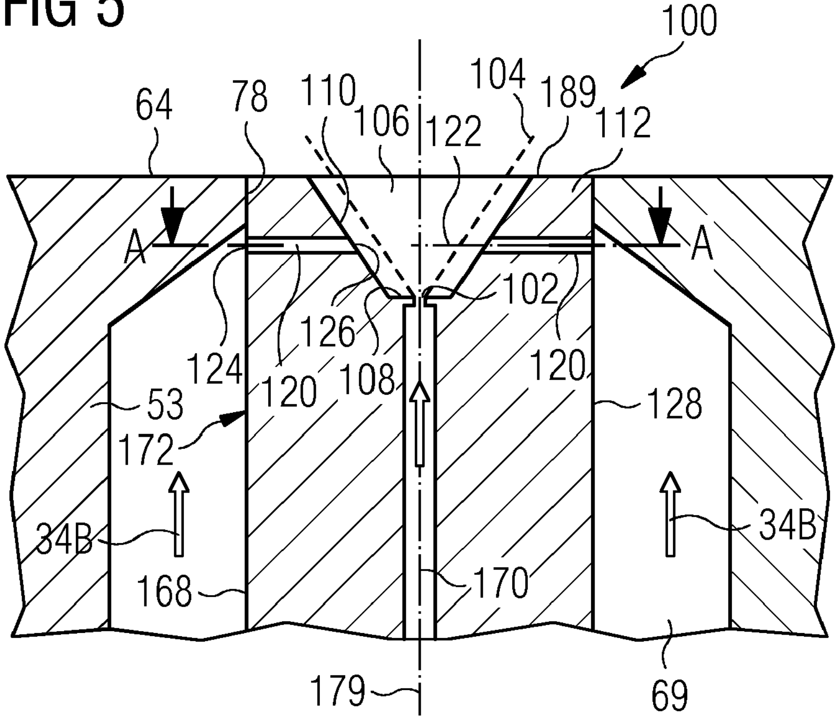
(54) COMBUSTOR BURNER ARRANGEMENT

(57) A fuel lance 100 for a burner 30 of a gas turbine combustor 16, the fuel lance 100 has an axis 179 and comprises a fuel lance body 68 defining a fuel flow passage 170, an end surface 189 defining a recess 106 and an array of radially extending air assist passages 120 that supply air to the recess 106. The recess 106 has a base surface 108 and a side surface 110. The fuel passage 170 has a fuel outlet 102 in the base surface 108 and the air assist passages have air outlets 124 in the side surface 110.

FIG 5



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Description

FIELD OF INVENTION

[0001] The present invention relates to combustion equipment of a gas turbine engine and in particular a liquid fuel lance for a burner arrangement of the combustion equipment.

BACKGROUND OF INVENTION

[0002] Gas turbines including dry low emission combustor systems can have difficulty lighting and performing over a full load range when using liquid fuels. Often this can be because of fuel placement and subsequent atomization of the fuel in mixing air flows particularly at low loads. Ideally, the fuel droplets need to be very small and injected into an appropriate part of the airflow entering the combustor's pre-chamber in the vicinity of a burner arrangement to burn in the correct flame location. Also the fuel droplets should not contact any wall surface but at the same time the fuel droplets need to come close enough to the igniter so that the igniter can ignite the vaporised fuel on start up. If the fuel droplets contact a surface this can lead to carbon deposits building up or lacquers forming and which can alter airflow characteristics or even block air and/or fuel supply holes.

[0003] The liquid pilot injection lance can have additional air assistance to aid atomisation of the liquid fuel over a range of fuel flows. This air assistance can be a supplied via a number of air outlets completely surrounding a fuel orifice or filmer. This liquid pilot injection lance is in a region prone to liquid fuel contact and as a result tends to incur carbon deposits. These carbon deposits block the air assistance holes and subsequently prevent successful atomisation of the fuel. Poor atomisation of the pilot fuel also causes problems with ignition of the fuel at start-up. This is a common issue with gas turbine fuel injection systems and carbon build up is a common problem. Consequently, liquid pilot injection lances are regularly replaced and are considered a consumable part. This is undesirable because such replacement is expensive, causes the gas turbine to be off-line halting supply of electricity or power for example, and can be unscheduled.

[0004] Known fuel lances have elongate bodies arranged along a main axis and configured to convey fuel and air along its axial length to its tip. A fuel orifice sprays fuel in a generally diverging cone shape from the tip and which is impinged upon by the air and broken up into small droplets. The fuel and the air are both directed in an axial direction away from the fuel lance and into a combustor pre-chamber where a main air supply further mixes the fuel and air. This axial projection of the fuel and air from the fuel lance can cause the fuel droplets to be forced too far into the pre-chamber and away from the igniter. This can result in poor ignition and relight in certain circumstances.

SUMMARY OF INVENTION

[0005] One objective of the present invention is to prevent carbon deposits forming on components. Another objective is to prevent carbon deposits forming on a fuel lance of a combustor. Another object is to improve the reliability of igniting the fuel in a combustor. Another objective is to improve the entrainment of fuel droplets in an air flow. Another objective is to improve the atomisation of liquid fuel in a combustor. Another objective is to prevent liquid fuel contacting a surface within the combustor. Another objective is to reduce or prevent scheduled or unscheduled shut down of the engine for maintenance attributed to replacing or cleaning combustor components subject to carbon deposits and particularly the liquid fuel lance.

[0006] For these and other objectives and advantages there is provided a fuel lance for a burner of a gas turbine combustor, the fuel lance has an axis and comprises a fuel lance body defining a fuel flow passage, an end surface defining a recess and an array of radially extending air assist passages that supply air to the recess, the recess has a base surface and a side surface, the fuel passage has a fuel outlet in the base surface and the air assist passages have air outlets in the side surface.

[0007] At least one of the air assist passages may be axially angled α between +/-15° from a radial plane. An angle α greater than 0° to +15° is away from the end surface. An angle α less than 0° to -15° is towards the end surface.

[0008] At least one of the air assist passages is radially aligned. Radially aligned means that the air assist passage is directly in line with the axis of the fuel lance or at least a central axis of the fuel outlet.

[0009] At least one of the air assist passages may have a central axis which may be off-set a distance R from a radial line. The radial line emanates from the axis of the fuel lance. The offset distance R is up to 0.2 of the wall width and in an exemplary embodiment the offset distance R is approximately 0.1 of the wall width. The wall width is the thickness or width of the remaining surface of the end surface of the fuel nozzle excluding the recess.

[0010] The side surface of the recess may be divergent relative to a cross-sectional area in an axial direction away from the base surface. The side surface may be angled ϑ between 45° and 90° from a radial line emanating from the axis of the fuel lance. In one exemplary embodiment the side surface 110 is angled at approximately 60°.

[0011] The depth or axial dimension of the recess may be between one and three times the wall width and in particular twice the wall width.

[0012] The recess may have a surface which has a shape of any one of the group comprising a part-sphere, a part- ovoid or a cuboid.

[0013] A fence may extend axially away from the end surface. The fence may extend approximately 180o about the axis of the fuel lance. The fence may extend about the longitudinal axis an angle β approximately 120°, but can extend about the longitudinal axis an angle β up to 270°.

[0014] The annular array of air assist passages may comprise at least one opposing pair of air assist passages that are aligned with one another across the recess.

[0015] The annular array of air assist passages may comprise at least one opposing pair of air assist passages that are aligned with one another across the recess and are off-set from the radial line.

[0016] At least one of the air assist passages of the annular array of air assist passages may be axially off-set from at least one other air assist passage.

[0017] The fuel outlet may be any one of a group comprising a single outlet, a plurality of outlets or a swirler outlet.

[0018] The fuel lance body may comprise an air manifold and the at least two of the air assist passages of the annular array of air assist passages are fed with air from the manifold.

[0019] The fuel lance body may comprise at least one air supply passage that is generally axially aligned.

[0020] The air assist passages extend to an external surface of the fuel lance body.

[0021] There may be eight air assist passages symmetrically spaced about the axis and are radially aligned.

[0022] It should be understood that the term 'between' also includes the limiting features or values themselves such that, for example, 'between -15° and +15°' includes both -15° and +15°.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] Further features, properties and advantages of the present invention will become clear from the following description of embodiments in conjunction with the accompanying drawings.

FIG. 1 shows part of a turbine engine in a sectional view in which the present invention is incorporated,

FIG. 2 shows a perspective schematic view of a section of a combustor unit of turbine engine and in detail a burner arrangement including a pilot burner surrounded by a main burner, the pilot burner having a known liquid fuel lance and an igniter,

FIG. 3 shows a schematic perspective and cut-away view of part of the pilot burner and in detail a known liquid fuel lance,

FIG. 4 is a view along a combustor axis and onto the surface of the burner where the pilot burner is generally surrounded by the main burner,

FIG.5 is a cross-section along a longitudinal axis of a liquid fuel lance and part of the burner body in accordance with present invention,

FIG.6 is a section A-A shown in FIG.5 and shows an array of air assist passages in accordance with the present invention,

FIG.7 is an enlarged part of the cross-section shown in FIG.5 and shows an alternative embodiment of the liquid fuel lance,

FIG.8 is a section A-A shown in FIG.5 and shows an alternative array of air assist passages in accordance with the present invention,

FIG.9 is a similar sectional view to FIG.5 showing an alternative embodiment of the tip region of the liquid fuel lance,

FIG.10 is a similar sectional view to FIG.5 showing an alternative embodiment of the tip region of the liquid fuel lance,

FIG.11 is a similar sectional view to FIG.5 showing an alternative embodiment of the tip region of the liquid fuel lance,

FIG.12 is a view on Arrow B in FIG.11 and shows further detail of that embodiment.

DETAILED DESCRIPTION OF INVENTION

[0024] FIG. 1 shows an example of a gas turbine engine 10 in a sectional view and generally arranged about a longitudinal axis 20. The gas turbine engine 10 comprises, in flow series, an inlet 12, a compressor section 14, a combustor section 16 and a turbine section 18 which are generally arranged in flow series and generally in the direction of the longitudinal or rotational axis 20. The gas turbine engine 10 further comprises a shaft 22 which is rotatable about the rotational axis 20 and which extends longitudinally through the gas turbine engine 10. The shaft 22 drivingly connects the turbine section 18 to the compressor section 12. The combustor section 16 comprises an annular array of combustor units 16 only one of which is shown.

[0025] In operation of the gas turbine engine 10, air 24, which is taken in through the air inlet 12 is compressed by the compressor section 14 and delivered to the combustion section or unit 16. The combustor unit 16 comprises a burner plenum 26, a pre-chamber 29, a combustion chamber 28 defined by a double walled can 27 and at least one burner 30 fixed to each combustion chamber 28. The pre-chamber 29, the combustion chamber 28 and the burner 30 are located inside the burner plenum 26. The compressed air 31 passing through the compressor 14 enters a diffuser 32 and is discharged from the diffuser 32 into the burner plenum 26 from where a portion of the air enters the burner 30 and is mixed with a gaseous and/or liquid fuel. The air/fuel mixture is then burned and the resulting combustion gas 34 or working gas from the combustion chamber is channelled via a transition duct 35 to the turbine section 18.

[0026] The turbine section 18 comprises a number of blade carrying rotor discs 36 attached to the shaft 22. In the present example, two discs 36 each carry an annular array of turbine blades 38. However, the number of blade carrying rotor discs could be different, i.e. only one disc or more than two rotor discs. In addition, guide vanes 40, which are fixed to a stator 42 of the gas turbine engine 10, are disposed between the turbine blades 38. Between the exit of the combustion chamber 28 and the leading turbine blades 38 inlet guiding vanes 44 are provided.

[0027] The combustion gas 34 from the combustion chamber 28 enters the turbine section 18 and drives the turbine blades 38 which in turn rotates the shaft 22 to drive the compressor section 14. The guiding vanes 40, 44 serve to optimise the angle of the combustion or working gas on to the turbine blades 38. The compressor section 14 comprises an axial series of guide vane stages 46 and rotor blade stages 48.

[0028] The terms upstream and downstream refer to the flow direction of the airflow and/or working gas flow through the engine as described above or unless otherwise stated. The terms forward and rearward refer to the general flow of gas through the engine. The terms axial, radial and circumferential are made with reference to the rotational axis 20 of the engine or a combustor axis 50 or a pilot fuel lance 79 unless otherwise stated.

[0029] FIG. 2 is a perspective view of a part of the combustor 16 showing the burner 30, the pre-chamber 29 and part of the combustion chamber 28. The combustion chamber 28 is formed with a tubular-like shape by the double walled can 27 (shown in Fig. 1) having and extending along the combustor axis 50. The combustor 16 extends along the combustor axial 50 and comprises the pre-chamber 29 and the main combustion chamber 28, wherein the latter extends in a circumferential direction 61 around the combustor axis 50 and generally downstream, with respect to the gas flow direction, of the pre-chamber volume 29.

[0030] The burner 30 comprises a pilot burner 52 and a main burner 54. The pilot burner 52 comprises a burner body 53, a liquid fuel lance 56 and an igniter 58. The main burner 54 comprises a radial swirler 55 having an annular array of swirler vanes 60 defining passages 62 therebetween. The annular array of swirler vanes 60 are arranged generally about a combustor axis 50, which in this example is coincident with the combustor axis 50, and in conventional manner. The radial swirler 55 includes main fuel injection ports which are not shown, but are well known in the art. The main burner 54 defines part of the pre-chamber 29. The pilot burner 52 is located in an aperture 57 and generally radially inwardly, with respect to the burner / combustor axis 50, of the main burner 54. The pilot burner 52 has a surface 64 that defines part of an end wall of the pre-chamber 29. The end wall is further defined by the main burner 54.

[0031] The liquid fuel lance 56 is at least partly housed in a first hole 66 defined in the burner body 53 of the pilot burner 52. A pilot air flow passage 69 is formed between the liquid fuel lance 56 and the walls of the first hole 66. The liquid fuel lance 56 comprises an elongate fuel lance body 86 and a liquid fuel tip 72. The elongate fuel lance body 86 is generally cylindrical and defines a fuel flow passage 70. The liquid fuel tip 72 is mounted at one end of the elongate fuel lance body 86 and is located near to or at the surface 64. The liquid fuel lance 56 will be described in more detail with reference to Fig. 3. The igniter 58 is housed in a second passage 74 defined in the burner body 53 of the pilot burner 52. The end of the igniter 58 is located near to or at the surface 64. The igniter 58 is a well known device in the art and that requires no further description. In other combustors 16 it is possible that more than one liquid fuel lance and/or more than one igniter may be provided.

[0032] During operation of the gas turbine engine and more particularly at engine start-up, a starter-motor cranks the engine such that the compressor 14 and turbine 16 are rotated along with the shaft 22. The compressor 14 produces a flow of compressed air 34 which is delivered to one or more of the combustor units 16. A first or major portion of the compressed air 34 is a main air flow 34A which is forced through the passages 62 of the swirler arrangement 55 where the swirler vanes 60 impart a swirl to the compressed air 34 as shown by the arrows. A second or minor portion of the compressed air 31 is a pilot air flow 34B which is forced through the pilot air flow passage 69. The pilot air flow 34B can also be referred to as an air assistance flow. Liquid fuel 76 is forced through the fuel flow passage 70 and is mixed with the pilot air flow 34B and the main air flow 34A in order to atomise the liquid fuel. Atomisation of the liquid fuel into very small droplets increases surface area to enhance subsequent vaporisation.

[0033] The main air flow 34A generally swirls around the combustor axis 50. The radial swirler 55 generally directs the main air flow 34A in a radially inward direction towards the combustor axis 50. The swirler vanes 60 also impart a tangential direction component to the main air flow 34A to cause the bulk main air flow 34 in to a vortex having a circumferential direction of flow. This circumferential flow aspect is in addition to the general direction of the air and fuel mixture along the combustor axis 50 from or near the surface 64 towards the transition duct 35 (see Fig.1). The fuel and air mixture passes through the pre-chamber 29 and into the combustion chamber 28. The main air flow 34A forces the pilot air flow 34B and entrained fuel near to the igniter 58, which then ignites the fuel / air mixture.

[0034] To start the engine, a starter motor rotates the shaft 22, compressor 14 and turbine 18 to a predetermined speed when the pilot fuel is supplied and ignited. Once ignited the combustor internal geometry and the air flow patterns cause a pilot flame to exist. As the engine becomes self-powering the starter-motor can be switched off. As engine demand or load is increased from start-up, fuel is supplied to the main fuel injection ports and the main fuel supply is mixed with the main air flow 34A. A main flame is created in the combustion chamber 28 and which is radially outwardly located relative to the pilot flame.

[0035] Reference is now made to Fig.3, which shows a schematic perspective and cut-away view of part of the pilot burner 52 and in detail the liquid fuel lance 56. The liquid fuel lance 56 comprises the elongate fuel lance body 68 and the liquid fuel tip 72 which are elements that can be unitary or separate. The liquid fuel tip 72 is located and captured by a narrowing 78 at an end of the first hole 66 and forms a tight fit. At the end of the fuel flow passage 70, the liquid fuel tip 72 includes a swirl plate 80 which defines an array of fuel conduits 82 having inlets and outlets. The fuel conduits 82, only one of which is shown, are angled tangentially relative to a longitudinal or fuel lance axis 79 of the liquid fuel lance 56 to create a swirl in the fuel. Downstream of the swirl plate 80 is a fuel swirl chamber 84 and then a fuel outlet 86, which in this example is a fuel filmer. This fuel filmer 86 is divergent and produces a divergent cone of liquid fuel. In other examples, the fuel outlet 86 can be an orifice that produces a spray of fuel or a number of orifices, each producing a spray of fuel.

[0036] The liquid fuel tip 72 has an end surface 89 which directly faces the pre-chamber and is perpendicular to the longitudinal axis 79. The liquid fuel tip 72 forms an array of pilot air flow conduits 88 having inlets that communicate with the pilot air flow passage 69 and outlets 90 which surround the fuel filmer 86. The outlets 90 are formed in the end surface 89 and are therefore generally directed in an axial sense. In this exemplary embodiment, the pilot air flow conduits 88 are inclined or angled in both a circumferential sense and radially inwardly relative to the longitudinal axis 79 of the liquid fuel lance 56. In other embodiments, the pilot air flow conduits 88 may be axially aligned, or angled in only one of the circumferential sense or radially inwardly relative to the longitudinal axis 79. In this exemplary embodiment there are 8 pilot air flow conduits 88; although in other embodiments there may be more or fewer conduits.

[0037] Pilot liquid fuel flowing in the fuel flow passage 70 enters the inlets of the fuel conduits 82 and exits the outlets imparting a swirl to the fuel in the fuel swirl chamber 84. The swirling fuel forms a thin film over the fuel filmer 86, which sheds the fuel in a relatively thin cone. Pilot air flow 34B impinges the cone of fuel and breaks the fuel into small droplets. The swirling vortex of air from the outlets 90 atomises the fuel along with the main air flow 34A.

[0038] The pilot air flow 34B is particularly useful at engine start-up and low power demands when the main air flow 34A has a relatively low mass flow compared to higher power demands and because of the lower mass flow is less able to atomise the liquid fuel. Advantageously, the pilot air flow 34B provides cooling to the pilot fuel lance and helps prevent fuel coking and carbon build up on the pilot fuel lance.

[0039] **FIG.4** is a view along the combustor axis 50 and on the surface 64 of the burner 30 where the pilot burner 52 is generally surrounded by the main burner 54. The liquid fuel lance 56 and the igniter 58 are shown mounted in the burner body 53 of the pilot burner 52. The swirler arrangement 55 of the main burner 54 surrounds the surface 64 and directs the main airflow 34B via the annular array of passages 62. The annular array of swirler vanes 60 and passages 62 are arranged to impart a tangential flow component to the main air flow 34A such that when the airflow portions from each passage 62 coalesce they form a vortex 34C generally about the burner axis 50. In this embodiment, the vortex 34C rotates generally anticlockwise as seen in Fig.4; this vortex 34C could also be said to be rotating in a clockwise direction as it travels in a direction from the surface 64 to the transition duct 35 through the pre-chamber 29 and then the combustor chamber 28.

[0040] In this exemplary embodiment, the vortex 34C is a single vortex, but in other examples the arrangements of pilot burner 52 and the main burner 54 can create a number of vortices rotating in either the same direction or different directions and at different rotational speeds.

[0041] The positions of the liquid fuel lance 56 and the igniter 58 are arranged so that the swirling or rotating main air flow 34A passes over or around the liquid fuel lance 56 and then on to the igniter 58. As the main airflow forms a vortex 34C about the axis 50, the liquid fuel lance 56 and the igniter 58 are positioned at approximately the same radial distance from the axis 50.

[0042] Thus as the fuel lance 56 injects or sprays liquid fuel into the pre-chamber 29 the main airflow 34C entrains the fuel and transports it towards the igniter 58, where ignition can take place.

[0043] The vortex 34C has many different stream velocities within its mass flow. In this example, the portion of the vortex denoted by arrow 34Cs is travelling at a lower velocity than the portion of the vortex denoted by arrow 34Cf. Main air flow portion 34Cs is radially inwardly of main air flow portion 34Cf with respect to the axis 50. Main air flow portion 34Cs is at approximately the same radial position as the radially inner part of the pilot fuel lance 56 and the main air flow portion 34Cf is at approximately the same radial position as the radially outer part of the pilot fuel lance 56.

[0044] The present invention will now be described with reference to Figs.5-12 where a liquid fuel lance 100 can be interchanged with the previously described liquid fuel lance 56 as described above. Therefore, the liquid fuel lance 100 is intended to replace the liquid fuel lance 56 without further adaptation of the burner or combustor equipment. Therefore, no further explanation of those features is necessary.

[0045] Referring now to **Fig.5** which is a cross-section along a longitudinal axis 179 of the fuel lance 100 and part of the burner body 53 and **FIG.6** which is a section on A-A in FIG.5. The fuel lance 100 in this example is a liquid fuel lance, but in other examples gaseous fuel can also be used. The fuel lance 100 has a tip 172 which engages with the orifice 78 in the burner body 53. The fuel lance body 168 defines a fuel flow passage 170 terminating in a fuel outlet 102. In use, fuel is sprayed in a cone shape 104 from the fuel outlet 102 and generally outwardly and axially with respect to the longitudinal axis 179.

[0046] The fuel lance 100 has an end surface 189 which defines a recess 106. The recess 106 has a base surface 108 and a side surface 110. The base surface 108 is generally planar and perpendicular to the longitudinal axis 179. The fuel outlet 102 is defined in or by the base surface 108 although it should be appreciated that the fuel outlet 102 could be replaced by a similar design to that shown in FIG.3 and is incorporated herein as an example; alternatively a number of fuel outlets 102 could be included in the recess.

[0047] The recess 106 has a generally frusto-conical shape with the side surface 110 being divergent moving away from the base surface 108. The angle of divergence of the side surface 110, as defined by walls 112 is approximately equal to a cone angle of the fuel spray 104. Referring to **FIG.7** the depth or axial dimension of the recess 106 is D and the width of the end surface of the wall 112 is L. The depth D of the recess 106 can be between one and three times the width L of the wall 112 i.e. D is between 1L and 3L. In this exemplary embodiment D = 2L. The side surface 110 can be angled ϑ between 45° and 90° from a radial line from the longitudinal axis 179. In one exemplary embodiment the side surface 110 is angled at approximately 60° In other words the side surface 110 can be angled between 45° and 0° from the longitudinal axis 179, with a preferable angle of 30° from the longitudinal axis 179.

[0048] Referring back to FIGS.5 and 6, the fuel lance 100 has an array of radially extending air assist passages 120 that supply air 34B directly into the recess 106. In this exemplary embodiment, the air assist passages 120 are in-line with a radial line 122 from the longitudinal axis 179. As can be seen the radial line 122 passes centrally through the air assist passage 120. Each air assist passage 120 has an inlet 124 and an outlet 126. The inlet 124 is defined by the surface of the recess and here the side surface 110 and the outlet 126 is defined by an external surface 128 of the fuel lance body 168. Eight air assist passages 120 are symmetrically spaced about the longitudinal axis 179 and being radially aligned, there are four pairs of air assist passages, e.g. 120A and 120B is one pair, that are aligned with one another and opposing one another.

[0049] In use, the air 34B issuing as jets from these two, and other pairs, of air assist passages 120A, 120B is directed at the longitudinal axis 179 and at one another. The air jets intercept the fuel spray breaking it up into small droplets and creating vortices to atomise the fuel so that the fuel and air mixture entering the pre-chamber and then the combustion chamber is as homogeneous and consistent as possible. This exemplary embodiment and the other variants described below further enhance the atomisation of the fuel and mixing of the fuel with air by virtue of the arrangement of the recess 106 and radially extending air assist passages 120. The radially extending passages 120 do not impart or minimise axial momentum to the fuel/air mixture by virtue of their radial direction of the airjets. Furthermore, opposing jets impinge on one another and reduce momentum of the air jets. Still further, the divergent shape of the recess 106 acts as a diffuser to further slow or reduce the velocity of the fuel/air mixture as it passes into the pre-chamber. By reducing the forward or axial momentum of the fuel/air mixture the fuel has a greater amount of time to mix and be vaporised. This improved mixing and vaporisation reduces carbon build up on combustor surfaces reducing the chance of blockages of any fluid outlets or the igniter as well as reducing emissions from the gas turbine engine. The amount of compressed air used to mix with the fuel can also be reduced thereby enhancing efficiency of the engine.

[0050] The foregoing description of Figs.5 and 6 are of an exemplary embodiment and now further examples and variants will be described which have some or all of the advantages mentioned. In commonality with all embodiments of the present invention the term 'radially extending air assist passages' is intended to include the variations described herein such that the air assist passages are generally radially aligned but meaning a defined range of angles away from a pure radial line are part of that term. A further common feature of all the embodiment is that the air assist passages have outlets in a recess and preferably in the side surface of the recess.

[0051] **FIG.7** is an enlarged view of part of the cross-section shown in FIG.5 and shows an alternative embodiment of the liquid fuel lance 100. Here the air assist passages 120 have an axial angle α in the range between +/- 15° from the radial line 122. The two air assist passage 120' and 120" are intended to show the range of angles whereas in any one section only one of the air assist passages 120' or 120" would be present. Nonetheless, it is possible for the array of air assist passages to have a number of passages angled up to - 15° and a number angled + 15°.

[0052] In the case of the air assist passages 120' being negatively angled (up to -15°) towards the orifice 102 or the base surface 108 the forward momentum of the jet is yet further arrested because the jets have an initial velocity in the opposite direction to the fuel/air mixture leaving the fuel lance 100 and entering the pre-chamber. In the case of the air assist passages 120" being positively angled (up to +15°) away the orifice 102 or the base surface 108 the forward momentum of the jets remain relatively low and can prevent undesirable stagnation of part of the fuel/air mixture within the recess.

[0053] **FIG.8** is a section A-A shown in FIG.5 and shows an alternative embodiment of the array of air assist passages where the central axes 130 of the air assist passages 120 are off-set a distance R from the radial line 122 in the plane as shown. The offset distance R is up to 0.2 of the wall width 112 L, and in an exemplary embodiment the offset distance R is approximately 0.1L. In this example, all of the array of air assist passages 120 are off-set a distance R from the radial line 122; however, only some of the air assist passages 120 need to be off-set and the number of off-set air assist passage 120 can determine the strength of the vortex created; the more air assist passage that are off-set generally the stronger the vortex created. The off-set air assist passages 120 create a vortex of fuel/air mixture within the recess 106 and yet further enhance the mixing. The off-set air assist passages 120 are effectively all tangential to a circle having a radius equivalent to the off-set distance R and therefore produce a vortex about the longitudinal axis 179. The off-set of these air assist passages 120 may be combined with any of the above or below described variants. The vortex can increase the break-up of the fuel spray and carry the fuel droplets on a longer path increasing the time for the droplets to pass into and through the prechamber thereby increasing the chance for the fuel to vaporise.

[0054] **FIG.9** is a similar sectional view to FIG.5 showing an alternative embodiment of the tip region 172 of the liquid fuel lance 100. In this embodiment the recess 106 is in a general shape of a part of a sphere or ovoid although other arcuate shapes are possible. The surface can be divided into two areas, the base surface 108 and the side surface 110 where the air assist passage outlets 124 and the fuel orifice 102 are respectively located.

[0055] In addition, FIG.9 shows a further feature of the invention where an air assist manifold 132 is included in the tip region 172 and which helps to distribute air pressure throughout the air assist passages.

[0056] **FIG.10** is a similar sectional view to FIG.5 showing an alternative embodiment of the tip region 172 of the liquid fuel lance 100. In this embodiment the recess 106 is in a general shape of a rectangle in cross-section or is a cuboid in three dimensions. The cuboid can take the form of a polygon in a plan view and the number of sides can be matched to the number of outlets 124.

[0057] In addition, FIG.10 shows that the air assist passages 120 are axially off-set from one another a distance X. In this embodiment it is possible to have a greater number of air assist passages 120 along the axial extent of the recess 106. An axial separation of opposing air assist passages 120C and 120D allows the jets of each to penetrate completely through the cone of fuel spray and thereby increasing atomisation and mixing of the fuel and air.

[0058] **FIG.11** is a similar sectional view to FIG.5 showing an alternative embodiment of the tip region 172 of the liquid fuel lance 100 and **FIG.12** is a view on Arrow B. In this embodiment a fence 136 extends axially from the end surface 189. The fence 136 extends about the longitudinal axis an angle β approximately 120°, but can extend about the longitudinal axis an angle β up to 270°. The fence 136 is positioned on the leeward side of the fuel lance 100 such that it shelters the fuel lance 100 and its fuel/air vortex from the main air flow 34A. The fence 136 can create further turbulence and enhanced mixing of the fuel and air mixture.

[0059] In addition, FIG.11 shows the fuel lance body 168 defining air supply passages 134 which are generally axially aligned with the longitudinal axis 179. Each air supply passage 134 feeds one air assist passage 120. In another arrangement, a number of air supply passages 134 can supply air to the manifold 132 for distribution to the air assist passage 120.

Claims

1. A fuel lance (100) for a burner (30) of a gas turbine combustor (16), the fuel lance (100) has an axis (179) and comprises
   a fuel lance body (68) defining a fuel flow passage (170),
   an end surface (189) defining a recess (106) and
   an array of radially extending air assist passages (120) that supply air to the recess (106), the recess (106) has a base surface (108) and a side surface (110),
   the fuel passage (170) has a fuel outlet (102) in the base surface (108) and the air assist passages have air outlets (124) in the side surface (110).

2. A fuel lance (100) as claimed in claim 1 wherein at least one of the air assist passages (120) is axially angled α between +/-15° from a radial plane.

3. A fuel lance (100) as claimed in claim 1 wherein at least one of the air assist passages is radially aligned.

4. A fuel lance (100) as claimed in any one of claims 1-3 wherein at least one of the air assist passages (120) has a central axis (130) which is off-set a distance R from a radial line 122.

5. A fuel lance (100) as claimed in any one of claims 1-4 wherein the side surface (110) of the recess (106) is divergent relative to a cross-sectional area in an axial direction away from the base surface.

6. A fuel lance (100) as claimed in any one of claims 1-5 wherein the recess (106) has a surface (108,110) which has a shape of any one of the group comprising a part-sphere, a part-ovoid or a cuboid.

7. A fuel lance (100) as claimed in any one of claims 1-6 wherein a fence (136) extends axially from the end surface (189).

8. A fuel lance (100) as claimed in any one of claims

1-7 wherein the annular array of air assist passages (120) comprise at least one opposing pair of air assist passages (120A, 120B) that are aligned with one another across the recess (106).

9. A fuel lance (100) as claimed in any one of claims 1-8 wherein the annular array of air assist passages (120) comprise at least one opposing pair of air assist passages that are aligned with one another across the recess and are off-set from the radial line (122).

10. A fuel lance (100) as claimed in any one of claims 1-9 wherein at least one of the air assist passages (120C) of the annular array of air assist passages is axially off-set from at least one other air assist passage (120D).

11. A fuel lance (100) as claimed in any one of claims 1-10 wherein the fuel outlet (102) is any one of a group comprising a single outlet, a plurality of outlets or a swirler outlet.

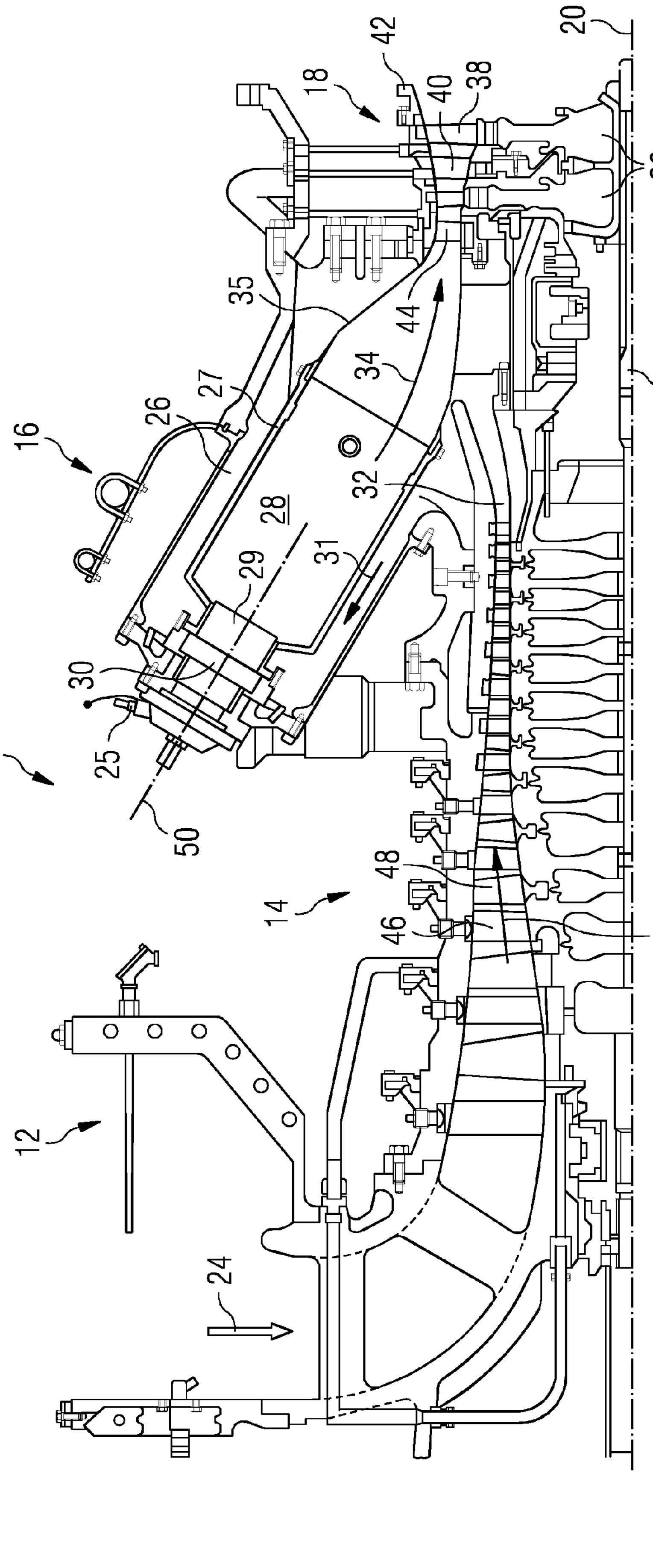
12. A fuel lance (100) as claimed in any one of claims 1-11 wherein the fuel lance body (68) comprises an air manifold (132) and the at least two of the air assist passages (120) of the annular array of air assist passages are fed with air from the manifold (132).

13. A fuel lance (100) as claimed in any one of claims 1-12 wherein the fuel lance body (68) comprises at least one air supply passage (134) that is generally axially aligned.

14. A fuel lance (100) as claimed in any one of claims 1-11 wherein the air assist passages (120) extend to an external surface (128) of the fuel lance body (168).

15. A fuel lance (100) as claimed in any one of claims 1-14 wherein there are eight air assist passages (120) symmetrically spaced about the axis and are radially aligned.

FIG 1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48
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FIG 2

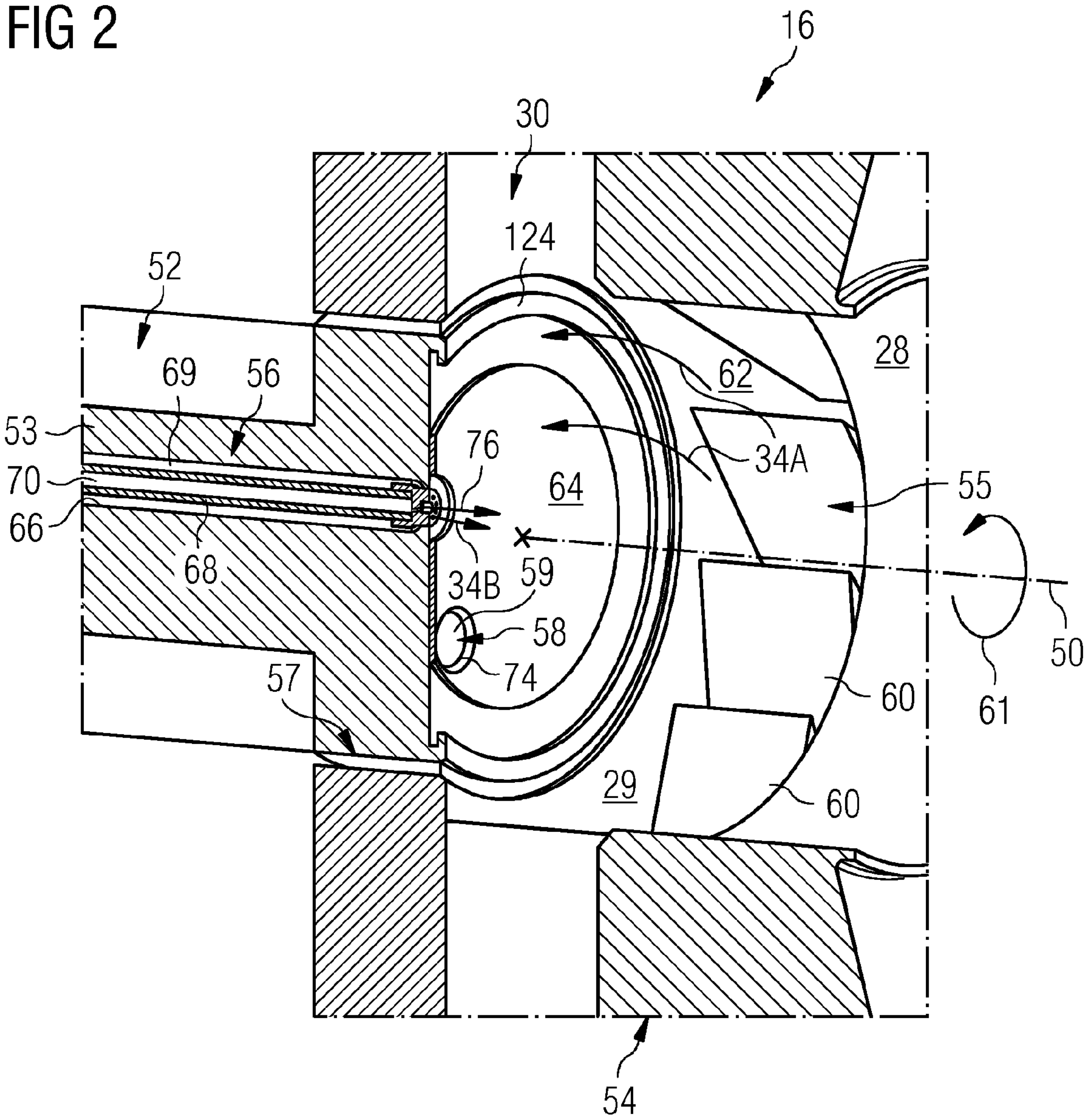

16
30
124
52
69
56
53
70
66
68
76
64
62
28
34A
55
34B
59
58
74
57
60
61
50
29
54

FIG 3 PRIOR ART

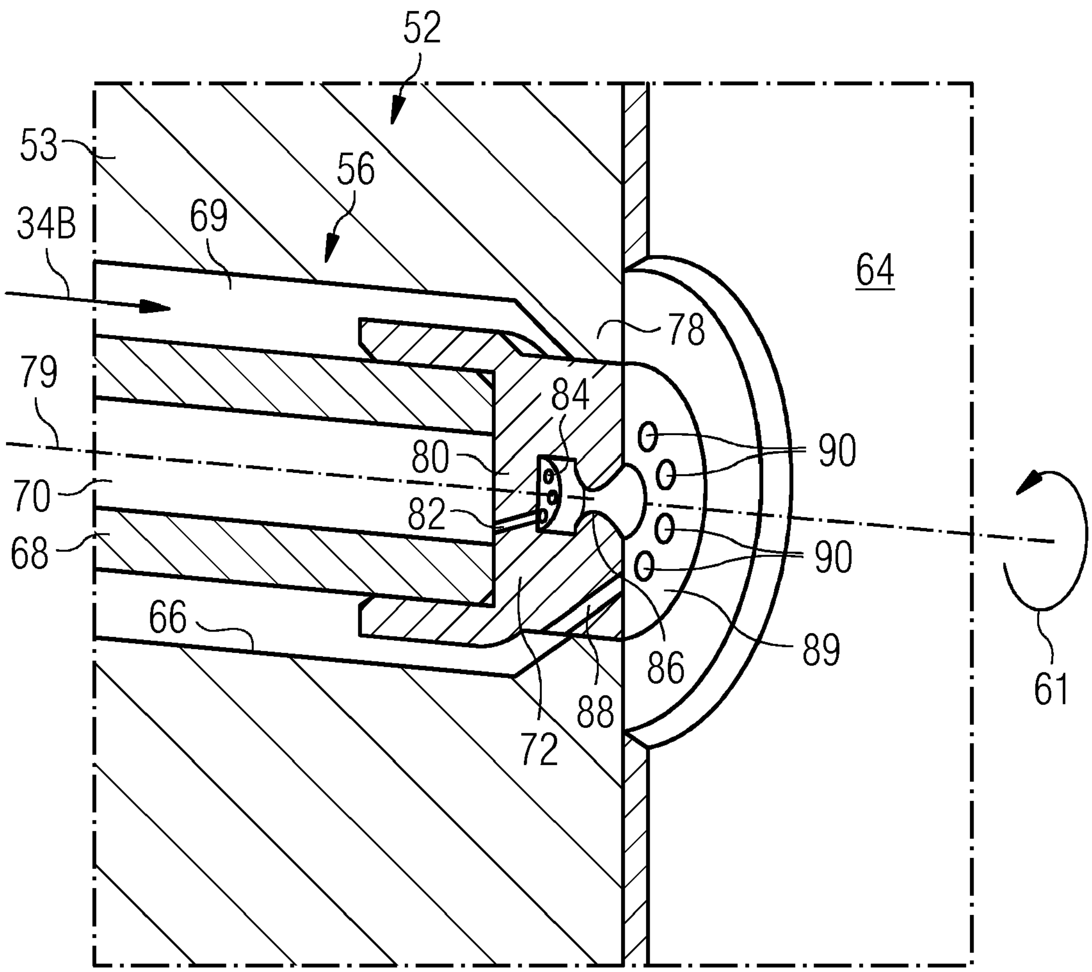


FIG 4

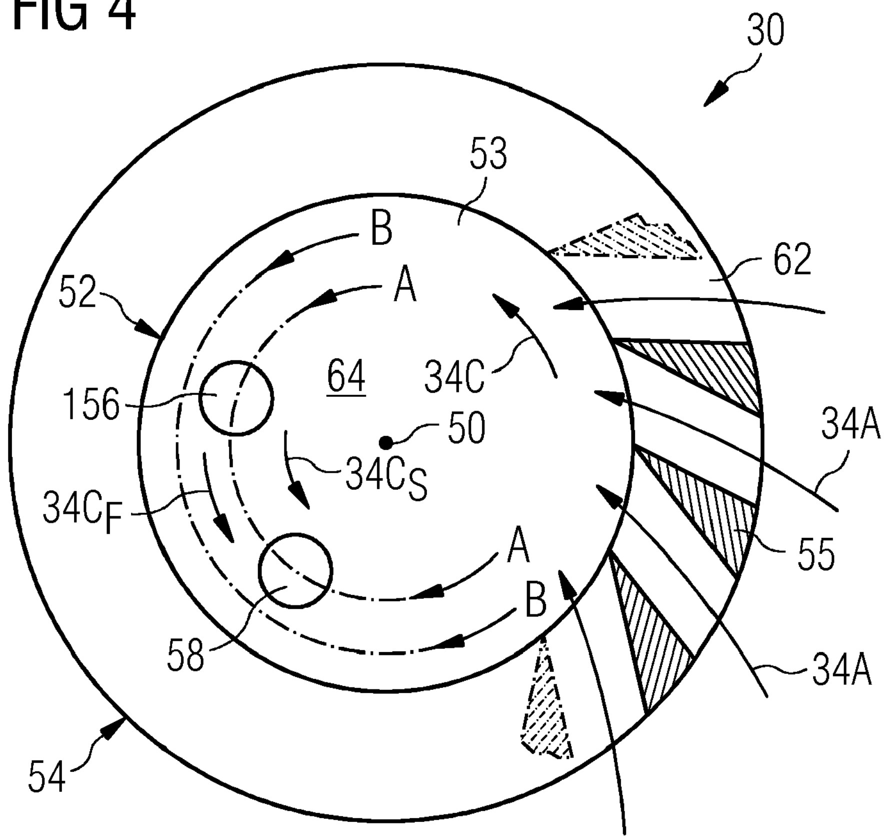


FIG 5

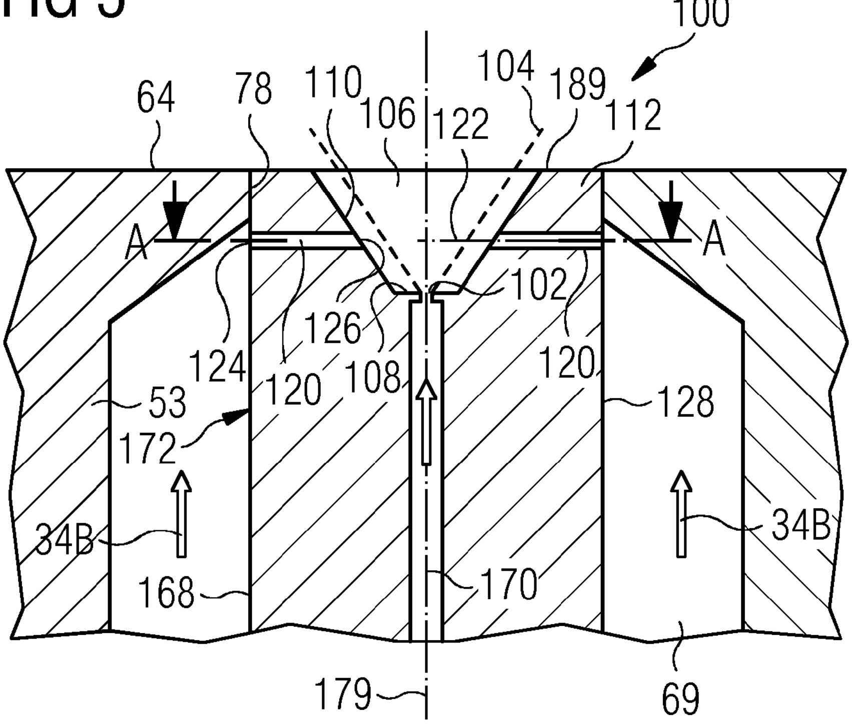

100
64
78
110
106
104
122
189
112
A
A
102
126
124
120
108
120
53
128
172
120
34B
34B
168
170
179
69

FIG 6

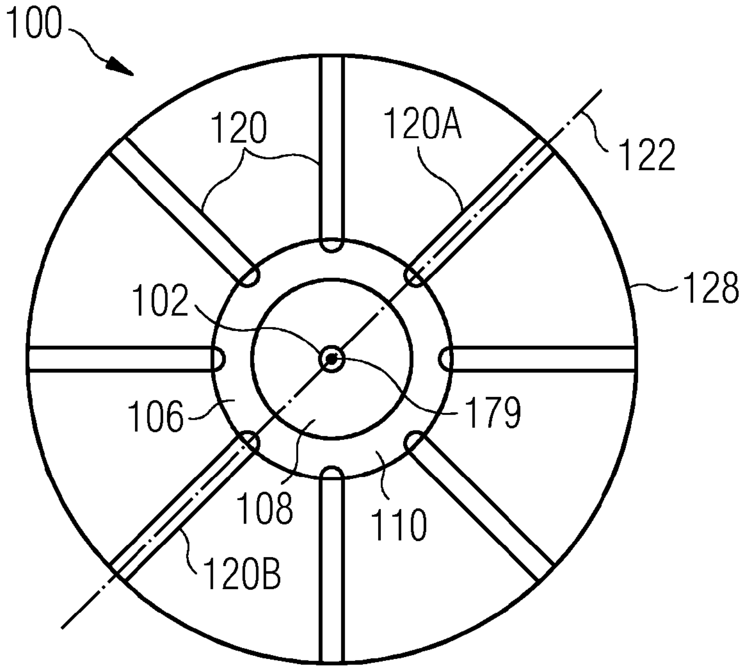

100
120
120A
122
128
102
179
106
108
110
120B

FIG 7

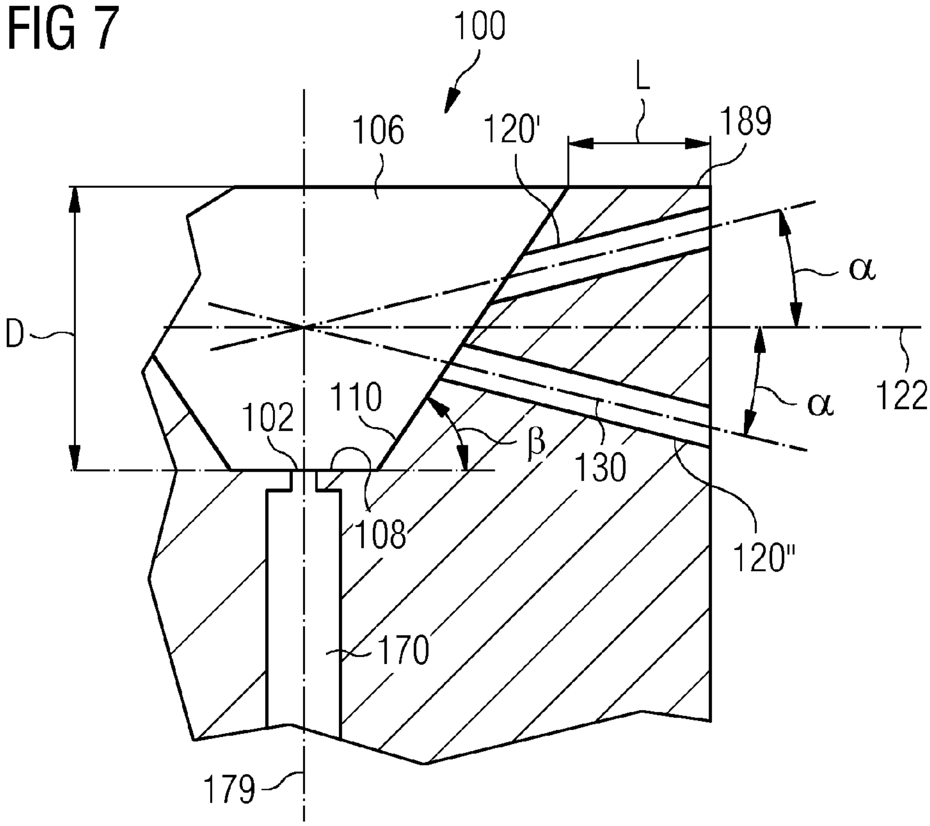

100
106
120'
L
189
α
D
122
α
110
102
β
130
108
120"
170
179

FIG 8

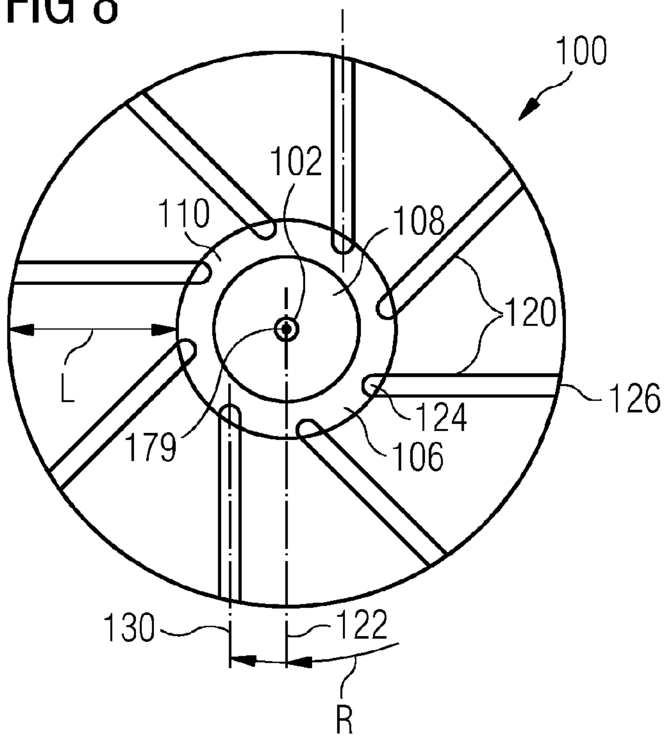

100
102
110
108
120
L
126
124
179
106
130
122
R

FIG 9

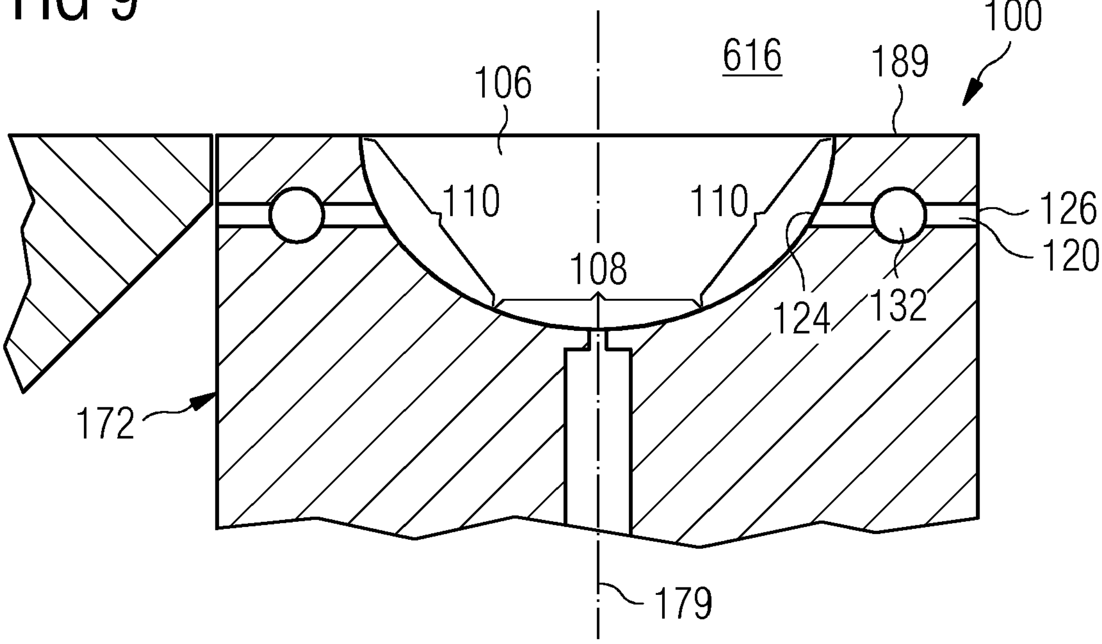

100
616
106
189
110
110
126
120
108
124
132
172
179

FIG 10

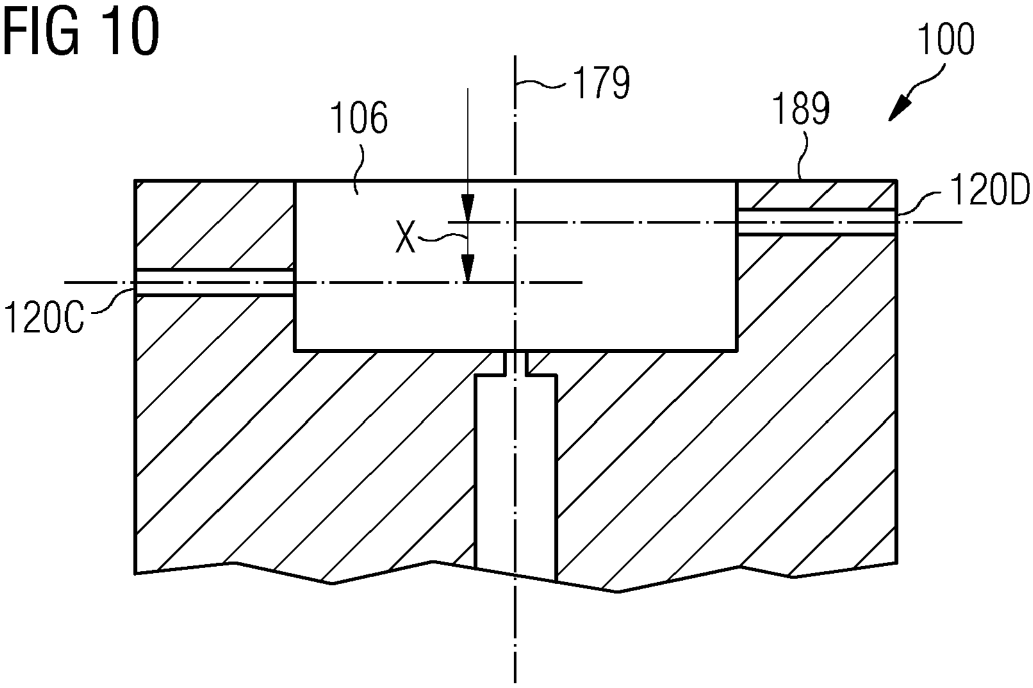

100
179
106
189
120D
X
120C

FIG 11

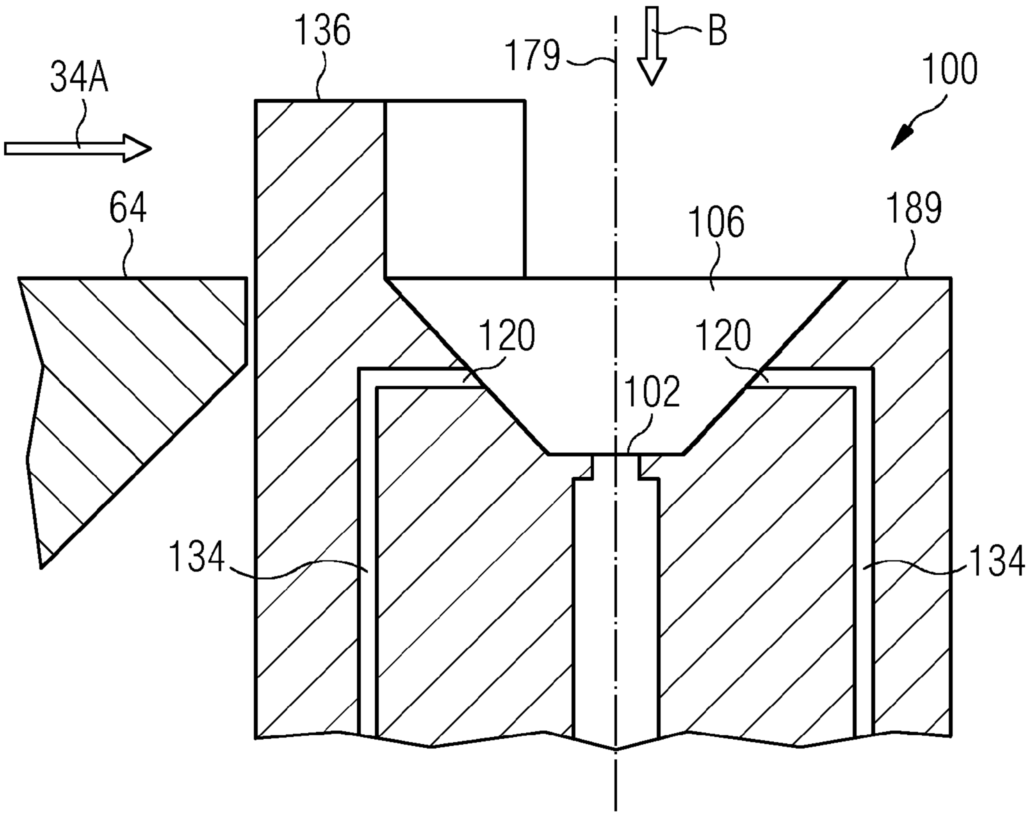
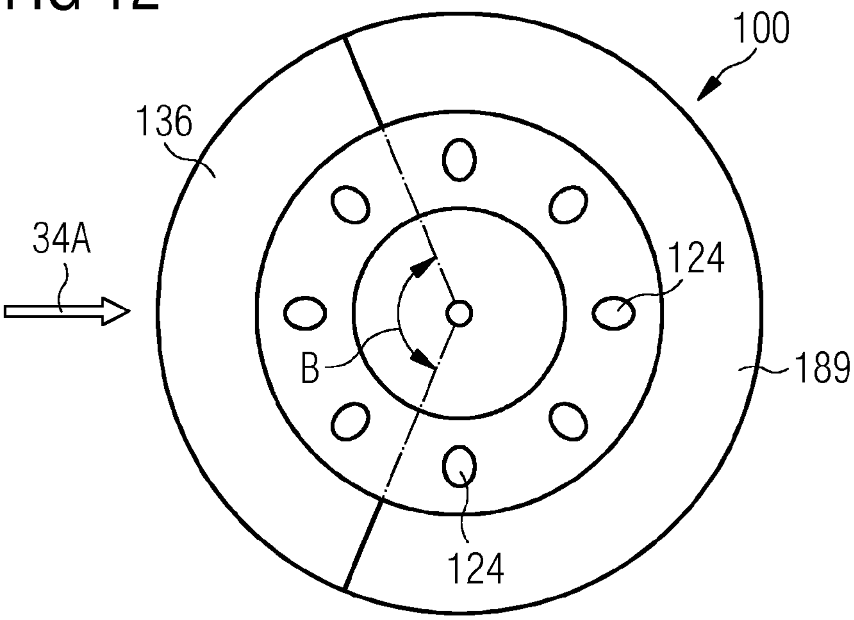

136
179
B
100
34A
64
106
189
120
120
102
134
134

FIG 12


100
136
34A
124
B
189
124

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EUROPEAN SEARCH REPORT

Application Number
EP 15 16 3058

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X	EP 1 489 358 A2 (HITACHI LTD [JP]) 22 December 2004 (2004-12-22) * figures 2-6 *	1,5	
A	US 2010/273117 A1 (EROGLU ADNAN [CH]) 28 October 2010 (2010-10-28) * the whole document *	1-15	
A	EP 2 693 124 A1 (SIEMENS AG [DE]) 5 February 2014 (2014-02-05) * the whole document *	1-15	TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	14 October 2015	Delval, Stéphane

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