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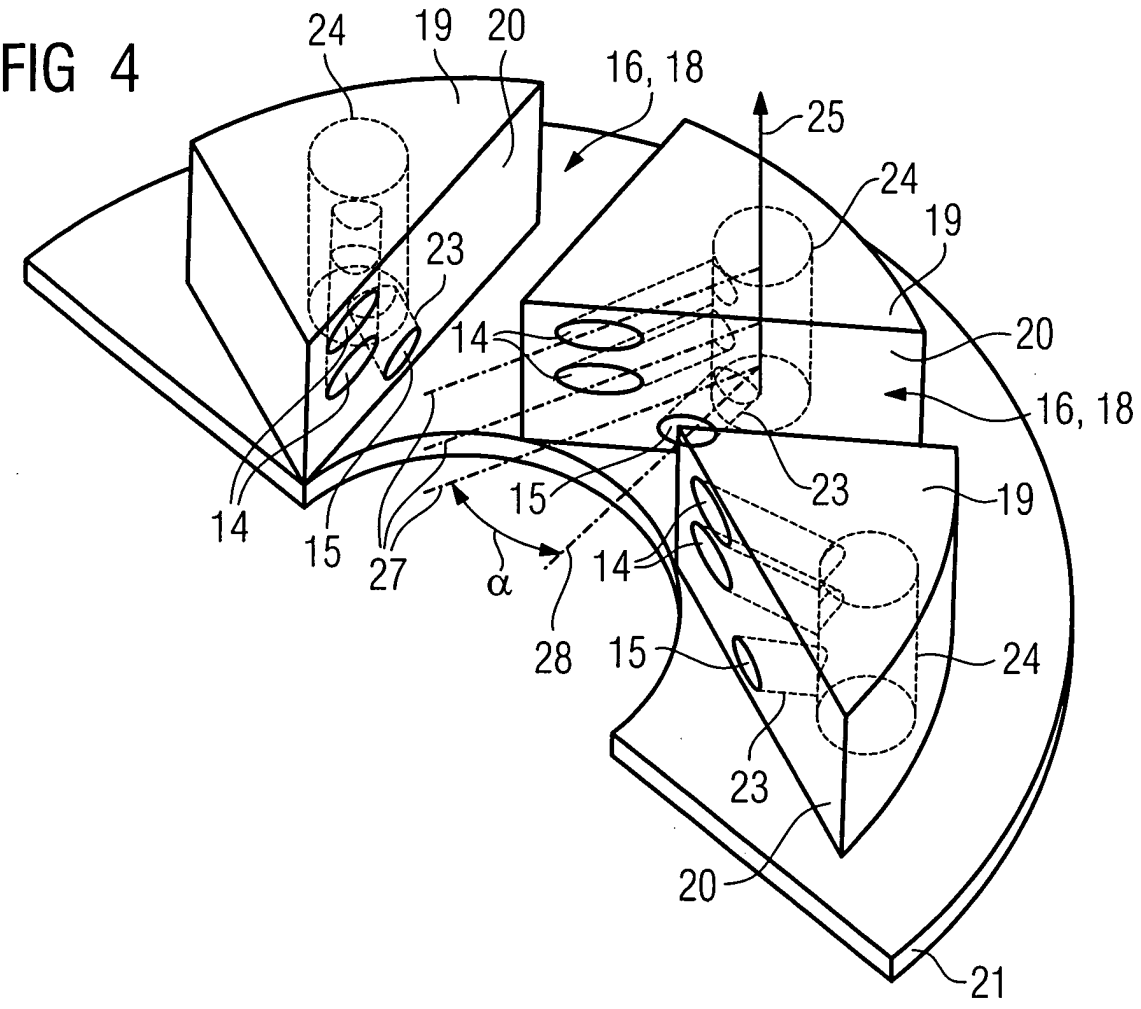
(54) **Fuel injection system**

(57) Disclosed is a fuel injection system (13), especially for LCV fuel, with a first fuel outlet opening (14) and a second fuel outlet opening (15), wherein the first and second fuel outlet openings (14,15) are arranged in a fuel/air mixing passage (16), the first fuel outlet opening (14) arranged closer to an exit (17) of the fuel/air mixing passage (16) than the second fuel outlet opening (15).

FIG 4



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Description

FIELD OF THE INVENTION

[0001] The invention relates to a fuel injection system and improvements for the further diminishment of air pollutants such as nitrogen oxides (NOx).

BACKGROUND OF THE INVENTION

[0002] Air pollution is a worldwide concern and many countries have enacted stricter laws further limiting the emission of pollutants from gas turbine engines or offer fiscal or other benefits for environmentally sound installations. Although the prior techniques for reducing the emissions of NOx from gas turbine engines are steps in the right direction, the need for additional improvements remains.

[0003] There are two main measures by which reduction of the temperature of the combustion flame can be achieved. The first is to use a fine distribution of fuel in the air, generating a fuel/air mixture with a low fuel fraction. The thermal mass of the excess air present in the reaction zone of a lean premixed combustor absorbs heat and limits the temperature rise of the products of combustion to a level where thermal NOx is not excessively formed. The second measure is to provide a thorough mixing of fuel and air prior to combustion. The better the mixing, the fewer regions exist where the fuel concentration is significantly higher than average, the fewer the regions reaching higher temperatures than average, the lower the fraction of thermal NOx will be.

[0004] Usually the premixing of fuel and air in a gas turbine engine 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 produces a mixing of fuel and air before the mixture enters the combustion zone.

[0005] Current designs for LCV (low calorific value) fuels, where the fuel air mixing is not optimal, place the fuel injection openings towards the trailing edge of swirler passages so as to minimise the unacceptable blockage that the high volumetric flows of fuel required for an LCV burner would have on the air flow through the swirler passage. The more the fuel injection openings move upstream the more the potential for air flow blockage is increased, thus causing physical damage to the burner and preventing safe operation through flashback, auto-ignition, machine acceleration, etc.

[0006] US 5,865,024 describes a dual fuel mixer with axial swirlers including hollow vanes with internal cavities which are in flow communication with a gas manifold and also having a plurality of gas fuel passages connected to internal cavities to inject gaseous fuel into an air stream.

[0007] The project summary of the "Cleaner Fossil Fuels Programme" originates from an inter-company project between Alstom Power Technology Centre, and Alstom Power UK Ltd. in association with Cranfield University, School of Engineering and Queens University Belfast and describes a design with radial swirler including hollow vanes. Each vane has internal cavities and shows fuel injection openings aligned very close to the trailing edge and all arranged at the same distance from an exit of a fuel/air mixing passage. The publication of the project summary can be obtained from the Department of Trade and Industry (dti) in the UK.

[0008] DE 3819898 A1 describes a vane with an internal fuel passage exiting through a slot. The swirler disclosed is a radial swirler.

SUMMARY OF THE INVENTION

[0009] An object of the invention is to provide a new fuel injection system, especially for LCV fuel, allowing for a better control of the pre-mixing of gaseous fuel and compressor air when operating especially LCV fuels to provide a homogeneous fuel/air mixture and thereby reduce formation of NOx. Another objective is to provide a swirler vane for an improved fuel injection system, especially for LCV fuels. A third objective is to provide a burner with an improved fuel injection system, especially for LCV fuels. A fourth objective is to provide a gas turbine with an improved fuel injection system, especially for LCV fuels.

[0010] This objective is achieved by the claims. The dependent claims describe advantageous developments and modifications of the invention.

[0011] The basic idea of this inventive fuel injection system is, that a small amount of the high volumetric flows of fuel, especially required for an LCV burner, hits and mixes with the compressor air earlier than the main part, thus improving the mixing of fuel and compressor air and consequently reducing the formation of pollutants and, at the same time, keeping the risk of blockage low without additional expenses in production.

[0012] The injection angle of the fuel jets in the inventive fuel injection system, controlling the fuel penetration across the swirler passage, still is acute angled relative to the flow of compressor air so as to minimise the obstruction to the air flow through the burner at all machine load conditions. However, slight adjustments in the fuel momentum perpendicular to the air cross-flow within the fuel/air mixing passage can have a marked impact on the final fuel mixing in the pre-chamber of the burner. Such changes may be done in a controlled way through the angular displacement of one or more fuel outlet openings. Changes to the fuel penetration and mixing can be achieved through changes to the positioning of one or more of the multiple fuel injection openings in the fuel/air mixing passages. Fuel/air mixing passages such as swirler passages are delimited by side faces of neighbouring swirler vanes, by the surface of a swirler vane support which is facing a burner head and by a surface of the burner head to which the swirler vanes are fixed. A swirler passage extends from a compressor air inlet opening to

an exit of the swirler passage positioned downstream from the compressor air inlet opening relative to the streaming direction of the compressed air.

[0013] Therefore an inventive swirler passage comprises a fuel injection system with at least one fluid passage where the corresponding fuel outlet opening is arranged in a side wall of the swirler passage close to the trailing edge of the side wall for injecting fuel into the swirler passage and at least one fluid passage, where the fuel outlet opening is arranged in a side wall of the swirler passage upstream, relative to the flow of compressor air, of the fuel outlet opening close to the trailing edge. This is achieved by rotating at least one of the fuel outlet openings about the centre line of a conduit to which the fluid passages connect inside the inventive swirler vane.

[0014] These fuel outlet openings are sized to allow the large volumetric fuel flows associated especially with low calorific value (LCV) fuels.

[0015] By such a design of the fuel injection system a controlled placement of a mixture of fuel and compressor air in the swirler passage is obtained and an increased homogeneity or alternatively a tailoring of the mixture of fuel and compressor air for improved NOx emissions is enabled.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The invention will now be further described, by way of example, with reference to the accompanying drawings in which:

Figure 1 shows a longitudinal section through a combustor,
Figure 2 shows a perspective view of a swirler of the prior art,
Figure 3 shows conduits and passages inside a swirler of the prior art,
Figure 4 shows conduits and passages inside an inventive fuel swirler,
Figure 5 shows a top view on a swirler vane of the prior art, and
Figure 6 shows a top view on an inventive swirler vane.

[0017] In the drawings like references identify like or comparable parts.

DETAILED DESCRIPTION OF THE INVENTION

[0018] Figure 1 illustrates a longitudinal section through a combustor. The combustor comprises relative to a flow direction: a burner with swirler 2 and a burnerhead 1 attached to the swirler 2, a transition piece referred to as combustion pre-chamber 3 and a main combustion chamber 4. The main chamber 4 has a diameter being larger than the diameter of the pre-chamber 3. The combustion chamber 4 is connected to the pre-chamber 3 via a dome portion 10 comprising a dome plate 11. In general, the transition piece 3 may be implemented as a one part continuation of the burner head 1 towards the main chamber 4, as a one part continuation of the main chamber 4 towards the burner head 1, or as a separate part between the burner head 1 and the main chamber 4. The burner head 1 and the main chamber 4 assembly show rotational symmetry about a longitudinally central axis 12.

[0019] A fuel conduit 5 is provided for leading fuel to the burner which is to be mixed with in-streaming air in the swirler 2. The fuel/air mixture 7 is then guided towards the primary combustion zone 9 where it is burnt to form hot, pressurised exhaust gases streaming in a direction 8 indicated by arrows to a turbine of the gas turbine engine (not shown).

[0020] In the view of Figure 2 a prior art fuel injection system 13, namely a swirler 2 of a gas turbine engine for LCV fuels, includes a plurality of swirler vanes 19 and a swirler vane support 21. The swirler vanes 19 are disposed about a central axis 12 and arranged on a swirler vane support 21 with a central opening 29. Swirler passages 18 are defined between side faces 20 of adjacent swirler vanes 19 and the inflowing compressor air 6 passes through these to enter the pre-chamber 3. The swirler passages 18 extend between compressor air inlet openings 26 and exits 17 at trailing edges of swirler vanes 19 relative to the flow of the compressor air 6.

[0021] In Figure 2 an entry of a swirler passage 18, in the following referred to as compressor air inlet opening 26, is indicated in dashed lines and an exit 17 of another swirler passage 18 is indicated in dotted lined. At the end of a swirler passage 18 compressor air 6 starts mixing with fuel which is added through first fuel outlet openings 14 aligned at the trailing edge of a side face 20 of a swirler vane 19. Fuel and air enter the pre-chamber 3 with a swirling motion about the central axis 12 of the swirler 2.

[0022] Figure 3 illustrates the internal structure of prior art swirler vanes 19 of the swirler 2 as illustrated in Figure 2. Each first fuel outlet opening 14 connects through a first fluid passage 22 to a conduit 24, which is connected to a fuel supply (not shown). The first fluid passages 22 of a swirler vane 19 are parallel to each other and have a narrower width than the conduit 24 to which they connect and extend inwardly from this conduit 24 at an inclined angle relative to a radial direction of the swirler 2. The longitudinal axes 27 of these first fluid passages 22 are oriented such that the fuel enters the central opening 29 of the swirler 2 roughly tangentially to the edge of the central opening 29.

[0023] With reference to Figure 4 an inventive swirler 2 is shown. The first and second fuel outlet openings 14,15 of the inventive swirler 2 do not align. Besides the first fuel outlet openings 14 as illustrated in Figures 2 and 3, second fuel outlet openings 15 do not align with first fuel outlet openings 14 along an axis parallel to the central axis 12 of the swirler 2, as well as the corresponding first and second fluid passages 22,23 are not parallel to each

other while still connecting to the same conduit 24. Therefore, first fuel outlet openings 14 are arranged closer to the exits 17 of the swirler passages 18 than the second fuel outlet openings 15.

[0024] The rotation of the second fuel outlet openings 15 and the corresponding second fluid passages 23 about the conduit centre line 25 by an angle alpha □ relative to the first fuel injection openings 15 and the corresponding first fluid passages 22 is more clearly visible in the top view of the swirler vane 19 shown in Figures 5 and 6.

[0025] Figure 5 depicts a swirler vane 19 according to the prior art including at least two fluid passages 22 where all fluid passages 22 have first longitudinal axes 27 aligned in parallel.

[0026] In Figure 6 an inventive swirler vane 19 is shown. It comprises at least first and second fluid passages 22,23, wherein a second longitudinal axis 28 of the second fluid passage 23 forms an angle □ relative to the first longitudinal axis 27 of the first fluid passage 22.

[0027] Note that although Figure 4 only shows one second fuel outlet opening 15 per swirler vane and the corresponding second fluid passage 23, clearly more than one second fluid passage 23 may be rotated about the conduit centre line 25. If more than one fluid passage 23 is rotated, not all fluid passages 23 need to be rotated by the same angle.

[0028] Although the inventive injection system is especially designed for LCV fuels, higher calorific value fuels, like natural gas, may be used with the same general geometry where simply first and second fluid passages 22,23 are of reduced cross-section compared to an LCV design.

Claims

1. A fuel injection system (13), especially for LCV fuel, comprising:

a first fuel outlet opening (14); and
a second fuel outlet opening (15), wherein the first and second fuel outlet openings (14,15) are arranged in a fuel/air mixing passage (16), the first fuel outlet opening (14) arranged closer to an exit (17) of the fuel/air mixing passage (16) than the second fuel outlet opening (15).

2. The fuel injection system (13) as claimed in claim 1, wherein the fuel/air mixing passage (16) is a swirler passage (18).

3. The fuel injection system (13) as claimed in claim 1, wherein the first and second outlet openings (13,14) are of different size.

4. The fuel injection system (13) as claimed in claim 3, wherein the first outlet opening (13) is smaller than the second outlet opening (14).

5. The fuel injection system (13) as claimed in claim 2, wherein the first and second fuel outlet openings (14,15) are outlet openings of first and second fluid passages (22,23), the first and second fluid passages (22,23) arranged inside the swirler vanes (19) and connected to conduits (24), the conduits (24) connected to a fuel gas supply.

6. The fuel injection system (13) as claimed in claim 5, wherein the first and second fluid passages (22,23) are tube-shaped.

7. Use of a fuel injection system (13) for injecting LCV fuel into a fuel/air mixing passage (16), wherein the fuel injection system (13) comprises:

a first fuel outlet opening (14); and
a second fuel outlet opening (15), wherein the first and second fuel outlet openings (14,15) are arranged in a fuel/air mixing passage (16), the first fuel outlet opening (14) arranged closer to an exit (17) of the fuel/air mixing passage (16) than the second fuel outlet opening (15).

8. A swirler vane (19), comprising:

a conduit (24) arranged inside the swirler vane (19) and connected to a fuel gas supply, especially an LCV fuel gas supply;
at least first and second fluid passages (22,23) arranged inside the swirler vane (19) and connected to the conduit (24); a side face (20) of the swirler vane (19);
a first fuel outlet opening (14) of the first fluid passage (22), the first fuel outlet opening (14) arranged on the side face (20);
a second fuel outlet opening (15) of the second fluid passage (23), the second fuel outlet opening (15) arranged on the side face (20); and
an angle alpha (□) formed between a first longitudinal axis (27) of the first fluid passage (22) and a second longitudinal axis (28) of the second fluid passage (23).

9. The swirler vane (19) as claimed in claim 8, wherein the angle alpha (□) has a maximum value corresponding to a position of the second longitudinal axis (28) normal to the side face (20).

10. A burner, especially for LCV fuel, for a gas turbine comprising a swirler vane (19) as claimed in one of the preceding claims.

11. A gas turbine with a combustion system comprising at least one burner according to claim 10.

FIG 1

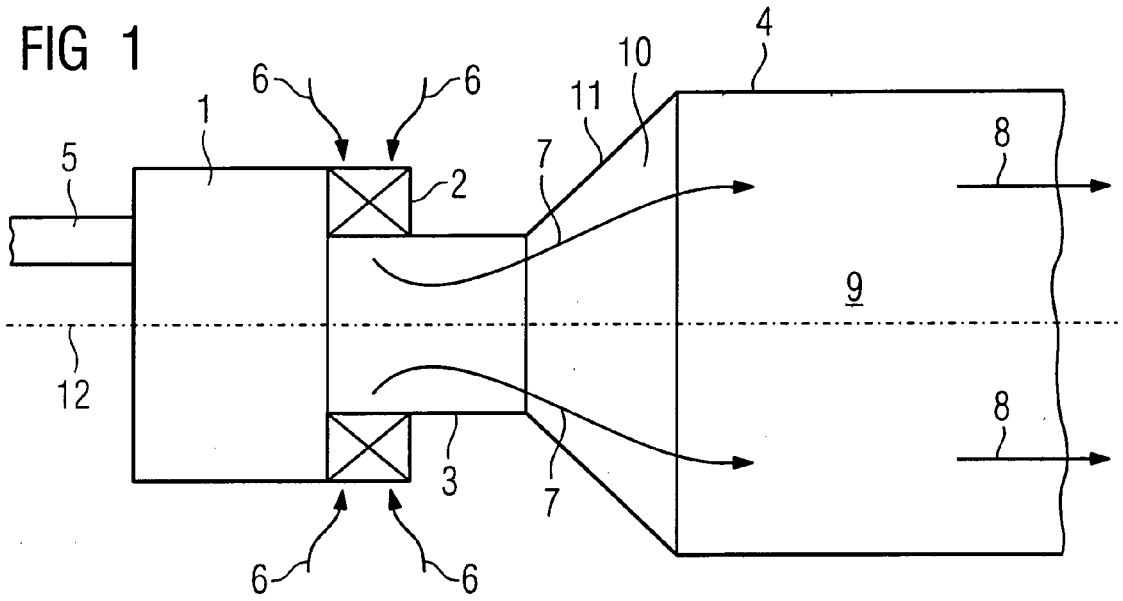


FIG 2
(Prior Art)

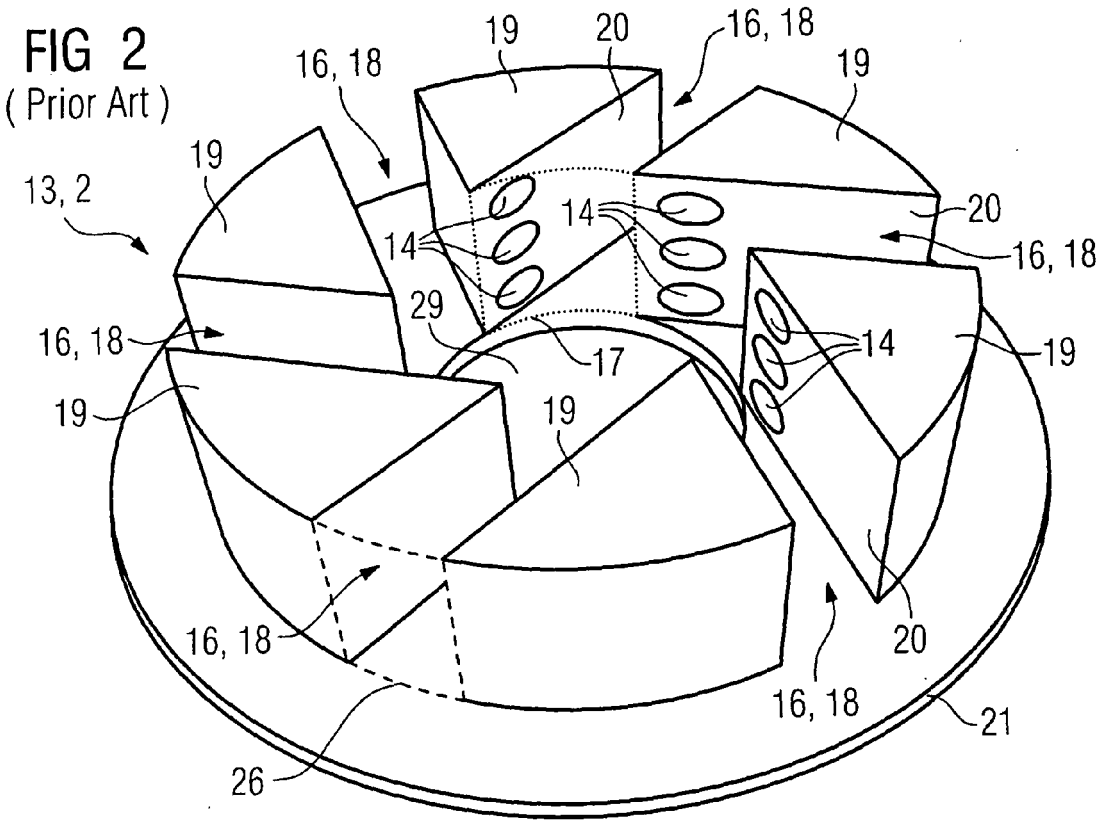


FIG 3
(Prior Art)

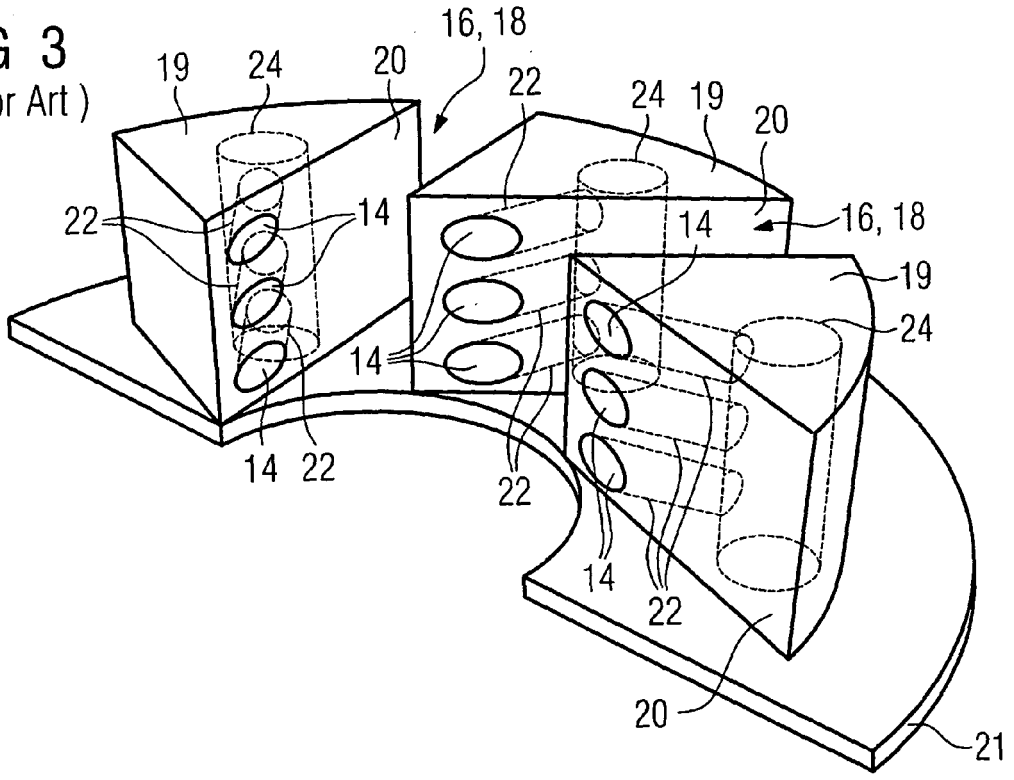


FIG 4

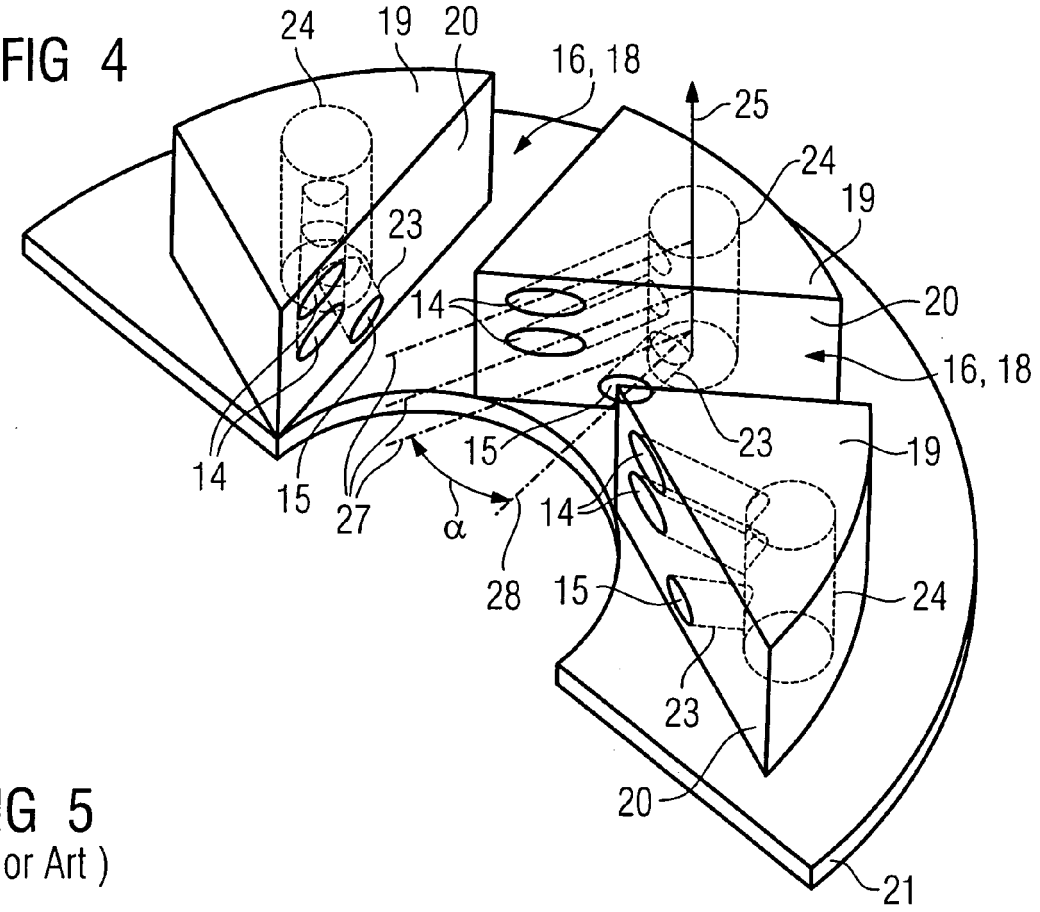


FIG 5
(Prior Art)

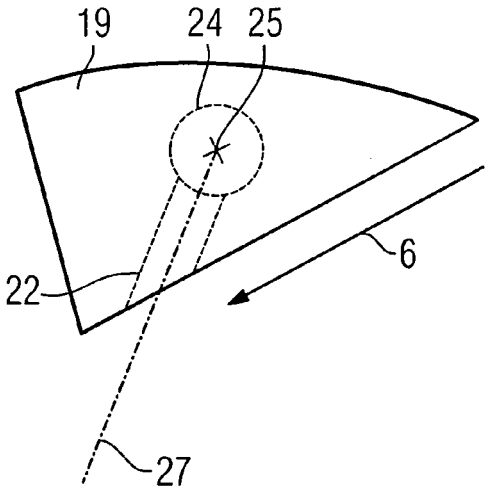
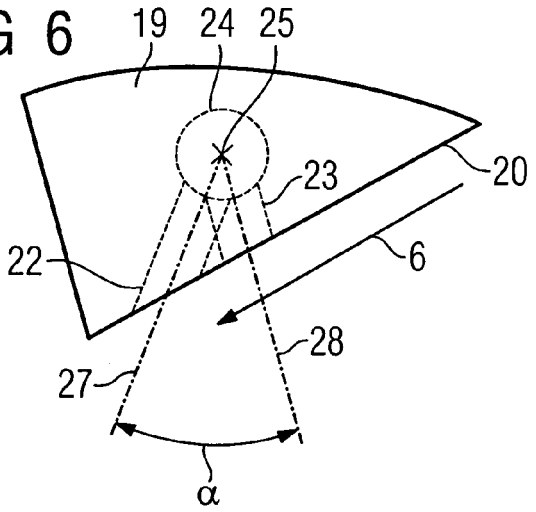


FIG 6



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Application Number
EP 06 02 3273

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	19 March 2007	Gavriliu, Costin

CATEGORY OF CITED DOCUMENTS

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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